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JOINT HIGHWAY RESEARCH PROJECT

FHWA/IN/JHRP-94/7
Final Report

ALTERNATIVES TO THE CURRENT AASHTO STANDARD BRIDGE SECTIONS

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Julio A. Ramirez
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PURDUE UNIVERSITY

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Joint Highway Research Project

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16. Abstract

The main objective of this study was evaluate feasible alternatives to the current AASHTO bridge girders used in Indiana. This evaluation included precast pretensioned bridge girders for spans from 30 to 130 feet with girder spacing between 5 and 10 feet and up to 12 feet for the longer spans. Other criteria included girder design concrete compressive strengths up to 7000 psi, 8" total concrete deck thickness with design strength of 4000 psi, grade 60 steel for slab reinforcement and stirrups and 1/2" special grade 270 low-relaxation strand for prestressing steel. Post-tensioning and pretensioned box girders were outside the scope of the study.

Approximately 100 alternate sections were received from surveys sent to various departments of transportation, consultants, and precasters in the United States. The girder cross sections were then evaluated for their structural efficiency and cost effectiveness. This was done using the computer program, PCBM, developed by Professor Robert H. Lee at Purdue University and currently used by INDOT.

The AASHTO I, II, & III girders were found to be economical for spans 30 to 70 feet. No alternate sections were therefore recommended in this span range. In the range from 70 to 90 feet the Illinois 54" section is considered the most economical. This section is currently being used as the only alternate section in Indiana. Other alternate sections were found to be more economical for spans over 90 feet. The Kentucky Bulb Tees were recommended for use in spans from 90 to 130 feet to provide considerable savings over the standard AASHTO girders. This would result in a savings of as much as 20 to 25 percent of the bridge superstructure for the longer spans.

Design Aids were created for these Kentucy Bulb Tees as well as for the AASHTO standards and the Illinois 54" section. The use of these sections is supported by this research study and recommended to INDOT. Adopting these alternate sections would result in considerable savings in Indiana's bridge construction.

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ALTERNATIVES TO THE CURRENT AASHTO STANDARD BRIDGE SECTIONS

Implementation Report

The objective of this study was to evaluate feasible alternatives to the current AASHTO bridge girders used in Indiana. This evaluation included precast pretensioned bridge girders for spans from 30 to 130 feet with girder spacing between 5 and 10 feet and up to 12 feet for the longer spans. Post-tensioning and pretensioned box girders were outside the scope of the study. Approximately 100 alternate sections were evaluated for their structural efficiency and cost effectiveness.

The AASHTO I, II, & III girders were found to be economical for spans from 30 to 70 feet. No alternate sections are therefore recommended in this span range. In the range from 70 to 90 feet the Illinois 54″ section is considered most economical. This section is currently being used as an alternate section to the AASHTO IV girder in Indiana. Alternate sections were found to be more economical for spans over 90 feet. The Kentucky Bulb Tees are recommended for use in spans from 90 to 130 feet to provide considerable savings over the standard AASHTO girders. This would result in a savings of as much as 20 to 25 percent of the bridge superstructure for the longer spans.

Design Aids were created for these Kentucky Bulb Tees as well as for the AASHTO standards. This was done in metric (SI) and inch-pound units to simplify design of the existing sections and implement design of the proposed Kentucky sections.

The Kentucky sections are currently being produced by local precasters in Kentucky. They have variable forms with webs from 6 to 8 inches and depths from 60 to 78 inches. The use of these sections is supported by this research study and recommended to INDOT. Adopting these alternate sections would result in considerable savings in Indiana's bridge construction.

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We would also like to thank the following Departments of Transportation, precasters, and consultants which participated in our survey.

Departments of Transportation: Colorado, Florida, Illinois, Indiana, Kentucky, Michigan, Ohio, Pennsylvania, Texas, Virginia, Washington, Wisconsin

Precasters: Elk River Concrete (Maple Grove, Minn.), Essroc (Melbourne, Ky.), Egyptian Concrete Company (Salem, Ill.), Hydro Conduit (Lafayette, In.), Hydro Conduit (Henderson, Ky.), Prestress Services (Lexington, Ky.), United Precast Inc. (Mt. Vernon, Ohio)

Consultants: American Consulting Engineers (Indianapolis, In.), Butler, Fairman & Seufert(Indianapolis, In.), RQAW & Associates (Indianapolis, In.), SIECO (Columbus, In.)

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Research was conducted at the Kettelhut Structural Engineering Laboratory computer facilities in the School of Civil Engineering, Purdue University, West Lafayette, Indiana.

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CHAPTER 1: INTRODUCTION

1.1 Background

When designers first began using prestressed concrete for bridge girders, they developed their own ideas of optimal bridge girder sections. Producers soon realized that it was too expensive to continuously design new forms for these customized girders. This led to the adoption of a series of AASHTO standard bridge girders in the late 1950's and early 1960's. As a result, prestressed concrete design became more widespread and efficient.

Since the development of these standard sections, there have been significant advances in materials as well as changes in design specifications relevant to applications of prestressed concrete. This created a need for changes in the original sections. Many state highway departments have thus revised the original AASHTO bridge girders or created their own standards to incorporate the advances in prestressed concrete. The Indiana Department of Transportation has not yet adopted a complete revised set of alternate bridge sections. However, considerable need for

re-evaluating existing standard sections is indicated by the use of alternate sections such as the Illinois 54" Prestressed Precast Concrete I-Beam as well as the consideration given to other possible alternate sections. Indiana is therefore in need of a systematic evaluation of alternate sections for improved efficiency and economy in bridge construction in the state.

1.2 Objective and General Scope

The objective of this investigation is to evaluate feasible alternatives to the current standard AASHTO bridge girder sections. This includes precast pretensioned bridge girders for spans from 30 to 130 feet with girder spacing between 5 and 10 feet and up to 12 feet for the longer spans. Other criteria includes girder design concrete compressive strengths up to 7000 psi, 8" total concrete deck thickness with design strength of 4000 psi, grade 60 steel for slab reinforcement, and 1/2" diameter special grade 270 low-relaxation strand for prestressing steel.

The work described in this report supports more efficient alternate sections for use in the State of Indiana as replacements for the current standard AASHTO sections.

The evaluation is divided into four main tasks consisting of evaluation of bridge girder sections, structural efficiency and cost-effectiveness, final beams and recommendations, and design charts.

1.3 Project Tasks

This section describes the tasks which comprised this research study.

1.3.1 Task 1: Evaluation of Bridge Girder Sections

The work conducted during this task included surveying the current use of precast pretensioned bridge girders from various departments of transportation, consultants, and precasters in the United States. Surveys were conducted through mail, telephone, and site visits. This survey provided information on alternate sections that are being utilized by other states. Cross sections of girders were obtained as well as information relevant to their design and use.

1.3.2 Task 2: Structural Efficiency and Cost-Effectiveness

This task included evaluating the structural efficiency and cost effectiveness of the alternate sections obtained in Task 1. These alternate sections were then compared to the standard sections which Indiana is currently using. The computer program, PCBM, developed by Robert H. Lee at Purdue University and currently used by INDOT was used for structural evaluation of the alternate sections. Relative costs were obtained through Task 1 and employed as a further comparison of the alternate sections with the current standards.

1.3.3 Task 3: Final Beams and Recommendations

This task included selecting the best beams in each span range for additional evaluation. Selection was based on least relative material costs as well as comparing criteria influencing the production of these girders. Cross sections and properties of the selected beams were sent to several precasters to obtain comments on their production.

Recommendations were then made for the final girders to be used in each span range.

1.3.4 Task 4: Design Charts

This task included preparing design aids for the final girders and the standard sections used by INDOT. The design aids were prepared for both simple and continuous spans as well as 6000 and 7000 psi girder concrete. They consist of three steps to select and design prestressed bridge girders. This includes choosing the appropriate girder for a given span range, and determining the required number and layout of prestressing strands.

1.4 Summary

In summary, Indiana is in need of a systematic evaluation of alternate sections for improved efficiency and economy in bridge construction in the state. The research described in this report evaluates alternate sections for use as replacements for the current standard AASHTO sections that Indiana is using. This includes precast pretensioned

bridge girders for spans between 30 and 130 feet. The evaluation is divided into four main tasks consisting of evaluation of bridge girder sections, structural efficiency and cost-effectiveness, final beams and recommendations, and design charts. The next chapter reviews the history of prestressed bridge girder design and relevant literature regarding optimization of these sections.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This chapter will give a brief history of current design practices for precast prestressed bridge girders as well as review literature relevant to this study. A concise discussion of the history and development of the precast prestressed bridge girder is followed by examples of current design philosophies in use today. Summaries of two reports pertaining to the optimization of highway bridge girders will also be reviewed. The first report is a thesis written by Kathryn Lynn Geren at the University of Nebraska in 1992. The second report is a nation wide survey done by Basile G. Rabbat and Henry G. Russell in 1982.

2.2 Historical Background

In the early 20th century the invention of prestressing changed the design world forever. The first use of prestressing in the United States was for confinement of hoop stresses that were developed in circular storage tanks. This technique soon led to linear prestressing for use in

the design of bridge girders. The first bridge constructed in the United States utilizing linear prestressing was the Walnut Lane Bridge in Philadelphia in 1949.

The successful construction of the Walnut Lane Bridge brought about an increase in the use of prestressing in the design and construction of bridges. The versatility and cost efficiency of prestressing made it a popular choice over the conventional reinforced concrete. The ability to make larger and more efficient bridges encouraged more contractors to enter the design business. Each designer used what he thought was the best girder design for each task. This involved making custom forms for each bridge constructed. It soon became obvious that the cost of producing new forms for each bridge would increase the overall expense of the project.

The cost increase became a major factor in the use of prestressed girders. The American Association of State Highway Officials (AASHO) and the Prestressed Concrete Institute (PCI) were prompted to begin work on standardizing girder design. The girders that were decided upon are still in use today. These girders include the original AASHO, today referred to as AASHTO Standard Sections Type I through IV, (designed in the late 1950's) and Types V and VI (developed in the early 1960's).

Since their acceptance, the use of the standard AASHTO-PCI sections greatly reduced the cost of the design and construction of prestressed bridges. It became possible to set up plants to mass produce the beams. This was accomplished using permanent forms instead of having to fabricate new forms for each series of beams being produced. In the beginning, this made prestressing a very popular design alternative. However, with standardization often comes stagnation.

The disadvantage behind standardization of the prestressed precast bridge girders was the reluctance of the industry to implement new alternate designs. The precast plants in their unwillingness to try new beam designs were as much at fault as the practicing engineers. The precasters made large initial investments in material as well as employee training in the mass production of the current beams. They felt that changes in their plants to accommodate new beams would have to bring significant economic potential. Some of the practicing engineers were hesitant because they were comfortable with the design and use of the current girders and did not want to deal with the nuances and expected performances of new girders. An example of this is the Washington Bulb Tee developed by Art Anderson in 1959. This series of beams was not used

nationally until 1988, the 30 year time span illustrates at least in part the universal reluctance to change [4].

However, an interesting fact is the desire and willingness of states to adopt their own style of girders as noted by the work in this report. Several studies have been done to find the optimal precast prestressed bridge girder. Several states designed and implemented their own style of girder to meet their economic needs and geographic locations. An example of this is the type of girders used in Pennsylvania. These beams are quite short and bulky compared to some of their counter parts, such as the Bulb Tee. The relatively short nature of the beams is due to the clearance problems associated with many of the roadway underpasses [4]. The potential to use these beams made it a viable alternative to steel bridge girders. The bulkiness of the girders is to account for the large prestressing forces that are developed in the beam to span the needed ranges. Other examples of geographical influence are seen in Colorado and Washington State. In these states the superior quality of aggregate enables the fabricators to utilize higher strength concrete which is needed to produce girders with 5″ and 6″ web thickness [4].

2.3 Studies Related to Optimization of Precast Bridge Girders

2.3.1 Optimized Sections for Precast Prestressed Bridge Girders by Rabbat and Russell

This study was done by Basile G. Rabbat and Henry G. Russell in 1982 in order to determine the most efficient girder type to use for the national or regional standard. The study was limited to bridges constructed using precast prestressed I or T sections for span ranges over 80 ft which utilized concrete strengths up to 7000 psi [7].

The research approach was divided into two phases. Phase 1 was the collection of information from precasters of bridge girders and highway agencies. Phase 2 was the evaluation of the structural efficiency and cost effectiveness of the beams. The standard AASHTO girder types were used as the basis for comparison. The parameters used in the testing were girder spacing, span length, deck thickness and concrete strength.

Once all the surveys were received and evaluated, the structural efficiency of the girders was determined using efficiency factors developed by Guyon and Aswad. The efficiency factor derived by Guyon ρ is based on maximizing

the section moduli for the top and bottom sections of a given girder type.

$$\rho = \frac{r^2}{y_t y_b} \tag{2-1}$$

r = radius of gyration

y_t, y_b = distance to top and bottom fibers

The efficiency factor developed by Aswad a is relative to spans exceeding 75 ft because of the bottom stresses governing the design of the girders.

$$\alpha = \frac{3.46 * S_b}{A\,h} \tag{2-2}$$

S_b = section moduli for bottom fibers

A = cross-sectional area

h = height of section

Using this equation, Aswad determined the girders with the highest efficiency ratio had the lowest cost per square foot of superstructure [7].

The cost analysis was done on the Bulb Tee's, Colorado, Washington and AASHTO girders. Consideration was also given to modified beams of the same type mentioned above with 6" webs. The parameters considered were girder spacing, concrete strength, deck thickness and girder span. Due to

the complexity of evaluating each girder, a computer program was developed to help in the calculations. The costs of labor, transportation and material varied greatly for each region so a relative cost of in-place construction was developed. The final cost of each beam was then divided into the deck area to give a relative cost index per square foot of deck.

Once all the results were tabulated, optimum cost curves were generated to determine the most efficient and economic girder. According to the study the Bulb Tee girders were the most economic when compared to the AASHTO girders. The cost savings were an average of 17 percent greater than with the AASHTO girders. The second most economical beams were the Washington series. The overall report stated that the Modified Bulb Tee's should be considered as a national standard over the current Modified AASHTO girders for the constraints established by the study.

2.3.2 Optimization of Precast-Prestressed Concrete Bridge I-Girders by K. L. Geren

This research project partially funded by PCI was the work of Kathryn Lynn Geren at the University of Nebraska in 1992. The objective of this report was to investigate the

potential of a national standard for continuous precast prestress I-girders. The standard girders in use today are primarily used for simple spans, therefore, there are some problems using them in the post-tension continuous area. Some examples of this are limited space in the web for postensioning strands and an insufficient amount of compressive area in the bottom fibers to accommodate negative moment regions. The scope of the project was not limited to the existing forms on the market today. A review of the existing I-girders and the optimization process used to choose an efficient girder were addressed in this project.

The survey was sent to 200 bridge constructors, state bridge designers, consultants and precast plants. From this survey there were nearly 90 responses. The responses of the poll consisted of structural details, fabrication procedures, handling and erection techniques.

Once all the surveys were obtained a parametric study was done. A computer program was developed to aid in the determination of the most structurally efficient and cost effective girder design. There were four major criteria used in the optimal design process. The parameters were; deflection, shear, prestress anchorage and flexure at critical negative and positive zones. The final goal of

this project was to design a girder that would, under service loads, "approach maximum capability based on ultimate strength criteria nearly simultaneously in the positive and negative moment areas, while meeting the requirements of working stress design." [4]

The final analysis determined the critical features controlling the optimal girder shape were the overall cross sectional area, the area of the bottom flange and the width of the top flange. The study concluded that the girder which minimized overall cross sectional area, maximized the cross sectional area of the bottom flange and maximized the width of the top flange produced the most structural efficient and cost effective girder for post-tensioning. Structural efficiency was determined by using the same efficiency factors described in Section 2.3.1. The preliminary girder shape was then critiqued by design professionals and suggestions led to the final girder shape. The Nebraska University Proposed Girder Series (Appendix K) was the final design submitted.

The Nebraska University Proposed Girder Series was then evaluated against the most efficient girders on the market to date. It was found that the Nebraska girders were able to span greater lengths while maintaining shallower depths

and less cost than any other girder in the range above 120 feet.

2.4 Summary

In summary, this chapter gave a brief history of current design practices for precast prestressed bridge girders as well as reviewed literature relevant to this study. Summaries of two reports pertaining to the optimization of highway bridge girders were reviewed. The first report was a nation wide survey done by Basile G. Rabbat and Henry G. Russell in 1982. The second report was a thesis written by Kathryn Lynn Geren at the University of Nebraska in 1992. The next chapter will include surveying the current use of precast pretensioned bridge girders from various departments of transportation, consultants, and precasters in the United States.

CHAPTER 3: EVALUATION OF BRIDGE GIRDER SECTIONS

3.1 Introduction

This task included surveying the current use of precast pretensioned bridge girders from various departments of transportation, consultants, and precasters in the United States. Surveys were conducted by mail as well as through telephone conversations and site visits. This survey provided information on many of the alternate bridge girder sections that are being utilized for spans between 30 and 130 feet. At the request of the Indiana Department of Transportation this study did not include box beams or post tensioning.

Two separate surveys were developed for mail distribution. One was sent to selected precasters in Indiana, Kentucky, Illinois, Wisconsin, Michigan, and Ohio. The other survey was sent to consultants in Indiana, and selected departments of transportation in the United States. These included Indiana, Florida, Illinois, Kentucky, Michigan, Washington, Texas, Wisconsin, Ohio, Pennsylvania, Virginia, and Colorado. Approximately 36 surveys were

mailed out and 22 were received. See Appendix A for a complete list of survey respondents.

The survey mailed to precasters included questions on design and construction details, fabrication details, transportation requirements and restrictions, and availability and costs. Surveys mailed to consultants and departments of transportation were similar except that fabrication details were excluded and structural durability questions were included. Survey forms and responses are included in Appendix A. In the following sections are the summaries of the major questions included in the survey and the most common responses are also presented.

3.2 Design and Construction Details

3.2.1 Girder Sections

A complete list of alternate prestressed concrete girder sections used by survey participants as well as their cross sectional dimensions is included in Appendix B. The majority of alternate sections received were utilized for spans between 70 and 130 feet. Some alternate sections were also received for spans between 30 and 70 feet.

Participants were asked the advantages of these alternate sections. Most participants replied that the alternate sections were more economical, providing longer span capabilities and wider beam spacing as well as being easier to transport.

3.2.2 Longest Spans

The longest spans built using single pretensioned girders were reported as 145' in Kentucky and Washington, 142' in Texas, 140' in Florida and Wisconsin, and 138' in Michigan.

3.2.3 End blocks

End blocks were not used in pretensioning applications except for the state of Colorado with the 5" and 6" webs and Minnesota and Wisconsin with the 6″ webs.

3.2.4 Concrete Properties

Most survey respondents used normal weight concrete of 150 lb/cf for their bridge girders. The strength at release

ranged between a minimum of 3500 in Michigan and a maximum of 6400 in Texas with most using a release strength between 4000 and 5000 psi. The 28 day design strength for the bridge girders was reported between 5000 and 8500 psi with most states using a design strength between 5000 and 6000 psi. The maximum 28 day design strength that beam designers are allowed to use ranged up to 8500 psi in Colorado with most states only allowing between 6000 and 7000 psi. Lightweight concrete was not used by the majority of the survey participants.

3.2.5 Strand Properties

The most common strand used by respondents for pretensioned girders is Grade 270, 1/2" and 1/2" special low relaxation strands. Stress relieved strands are permitted in some states, but they are rarely used. A few states also used 7/16" and 9/16" strands on non-Federal Aid projects. Most strands were spaced at two inches.

3.2.6 Girder Spacing

Spacing between pretensioned girders varied between 4 and 10 feet. The most common maximum girder spacing was 9 or 10 feet with a few exceptions of 12 feet in Florida and 15 feet in Pennsylvania.

3.2.7 Decks

Most survey respondents used a cast in place concrete deck with a 28 day design strength between 4000 and 4500 psi. Some states are also using precast pretensioned concrete deck panels or permanent metal deck forms with their bridge girders.

3.2.8 Design Loads

The majority of designs were for an HS20 live load with the exception of a few states which also design for HS25.

3.2.9 Design Charts

Most states surveyed had some type of design aid either in the form of charts and tables or computer software. Most of the charts showed relations between girder span, spacing and number of required prestressing strands.

3.3 Fabrication Details

3.3.1 Draping or Debonding

Most precasters preferred debonding prestressing strands while some are using draping. Several precasters expressed concern in draping strands due to the possibility of uplift and breakage of strands.

3.3.2 Epoxy Coating

Epoxy coated mild reinforcement is being used by most participants where as epoxy coated strands are not being used. Precasters sighted the dangers of using epoxy coated strands since they often slip and may explode out of the beam.

3.3.3 Web Thickness

Minimum web thickness was limited to 6" although a minimum of 7" is often preferred. Precasters expressed concern in using thinner webs as it is difficult to achieve proper consolidation in the bottom flange.

3.4 Transportation Requirements and Restrictions

3.4.1 Girder Length

The maximum length girder transported without a permit ranged from approximately 50 to 60 feet while the length with a permit was usually not limited. Most respondents sighted an upper limit of between 150 and 200 feet depending on the project site.

3.4.2 Instability

Instability problems were noted when transporting beams with long spans. Lateral bracing is often used and strong-backs are attached to the top flange when necessary. These problems are evaluated for each job as they are specific to the construction site.

3.5 Structural Durability

3.5.1 Design Life

Bridge girders were most often designed for 75 - 100 years.

3.5.2 Inspection

Inspection of bridge beams was normally performed every 2 years unless problems were sighted. Most common problems consisted of deterioration of beam ends due to leakage of joints, and spalling concrete at bottom flanges due to clearance problems. Cracks were normally not encountered. If seen, they were usually at the junction between the web and the lower flange near the ends of the beam or in the prestressing yard after strand release.

3.6 Availability and Costs

Cost data obtained in the survey is summarized in Appendix A. Unit costs for materials, labor, and transportation varied from state to state as did the cost

per linear foot of each girder sections. Approximate unit costs were selected from the surveys and used to evaluate a relative cost effectiveness of alternate sections.

3.7 Additional Information

In response to the survey question concerning tension in the concrete during service load conditions, the most frequent response was, tension is allowed in the concrete as stated in the AASHTO code specifications.

The use of interior diaphragms varies from state to state. The average response however, was that diaphragms were used with girder lengths over 50 feet. The frequency and spacing varied due to bridge configurations and local site conditions.

One respondent expressed the desire to use higher strength concerts in their bridge girders. Also an alternate section with variable forms is preferred with depths from 40" - 85".

Concern was also expressed as to the validity that precast deck panels act compositely with the cast in place part of the concrete deck. The concern was noted due to the

different physical properties of the two materials and their interaction during postensioning.

3.8 Summary

In summary, this task included surveying the current use of precast pretensioned bridge girders from various departments of transportation, consultants, and precasters in the United States. This survey provided information on many of the alternate bridge girder sections including design and construction details, fabrication details, transportation requirements and restrictions, structural durability, and availability and costs. The next chapter reviews the evaluation of these alternate sections. Comparisons were made using a structural efficiency factor, a computer program for structural evaluation, and graphs showing cost effectiveness.

CHAPTER 4: STRUCTURAL EFFICIENCY AND COST-EFFECTIVENESS

4.1 Introduction

This task included evaluating the structural efficiency and cost effectiveness of the alternate sections obtained through the survey conducted in the first task of the research project as presented in Chapter 3. These alternate sections were then compared to the standard sections which Indiana is currently using. Comparisons were made using a structural efficiency factor, a computer program for structural evaluation, and graphs showing cost effectiveness. Following is a detailed explanation of each of these tasks.

4.2 Structural Efficiency

Design of prestressed bridge girders is primarily based on flexure. It is therefore most optimal to maximize the section modulus and minimize the beam area. One method of quantifying this principle was developed by Guyon [7]. He derived an efficiency factor which is based on maximizing

the section moduli for top and bottom fibers for a given cross-sectional area. The efficiency factor is defined as:

$$\rho = \frac{r^2}{y_t y_b} \tag{4-1}$$

r = radius of gyration of section

y_t = distance from center of gravity to top fiber

y_b = distance from center of gravity to bottom fiber

The efficiency factor for various sections is plotted with respect to depth of the sections in Appendix C. This is one way of comparing the proposed alternate sections with the standard AASHTO sections. The higher efficiency factors denote a beam with a more efficient cross sectional area with respect to section moduli for top and bottom fibers. These factors are plotted with respect to depth and therefore have no relation to girder span or spacing. A more detailed structural evaluation and cost analysis is needed for further comparison. This is done with a computer program for structural evaluation.

4.3 Structural Evaluation

A detailed structural evaluation was performed on each of the proposed alternate bridge girders. This was done using the computer program, "PCBM", developed by Professor Robert H. Lee at Purdue University. This program is currently in use by the Indiana Department of Transportation (INDOT). Bridge girders were analyzed at their respective spans in the range of 30 to 130 feet. Girder spacing was varied between 5 and 10 feet. In addition, the girder spacing was extended to 12 feet for some of the alternate sections. Other assumptions which reflect INDOT's design procedures as well as the majority of survey responses include:

- 8" concrete deck
- concrete deck acts compositely with the girder
- deck concrete design strength of 4000 psi
- beam concrete release strength of 4500 psi
- beam concrete design strength of 6000 psi
- grade 60 steel for slab reinforcement and stirrups
- grade 270 steel for prestressing

- 1/2" special low relaxation strands
- HS20 live load
- AASHTO 1993, Bridge Design Specifications
- future wearing surface load of 35 psf

Initial structural evaluations were performed on all the bridge girders at 5, 8, and 10 foot girder spacing. The initial computer runs were also done with girders simply supported and strands designed in a draped pattern. These assumptions were selected as a simplification which would still provide an accurate relative ranking of the alternate sections. Further analysis was performed on the most efficient beams including spans made continuous for live load, debonded strand patterns, and a beam concrete design strength of 7000 psi.

Computer input for "PCBM" is a function of the above assumptions and the cross-sectional dimensions of the girder. The computer program then designs a prestressed bridge girder first by working stress and second by checking ultimate moment. Output includes girder cross-sectional properties, required number and pattern of prestressing strands, required stirrup spacing, as well as moments, shears, stresses, and deflections at various sections of the

span. The beam cross sectional area, number of prestressing strands, and stirrup spacing are then used in the cost-effectiveness analysis. See Appendix L for typical PCBM input and output files.

4.4 Cost Effectiveness

Due to the variation of costs from state to state, it is not possible to perform an exact cost comparison on alternate sections received from different regions of the country. This was also not the intent of the study. Approximate unit costs were therefore obtained from INDOT as well as through survey responses to perform a relative cost comparison of the alternate sections. These costs reflect relative costs of material, labor, and construction. See Appendix A for costs obtained from surveys.

4.4.1 Concrete Deck

Costs for the 8" concrete deck were obtained from INDOT's continuous floor slab design chart. See Appendix D for a copy of this chart. Effective spans were calculated

as the clear span between top flanges for standard girders and the clear span plus one half of the top flange for bulb tees. This design chart includes concrete at \$265/cy and both transverse and longitudinal epoxy-coated reinforcing steel at \$0.64/lb.

4.4.2 Girder Concrete - \$50/cy

This unit cost was selected from survey responses for the girder concrete. This figure reflects material only. Labor, transportation, and construction costs are included in the additional costs at the end of this section.

4.4.3 Prestressing Strands - \$0.30/ft

The unit cost of prestressing strands was obtained from the surveys.

4.4.4 Stirrups - \$0.45/lb

The stirrups were assumed to be #4 bars. The total number of stirrups required was calculated using the required stirrup spacing obtained from the computer output.

The length of each stirrup was computed as twice the girder height plus 2.3 times the top flange width. This length was found to be representative of the actual stirrup lengths used in the girder sections.

4.4.5 End Straps - $0.45/lb

End straps were assumed to be #3 bars placed at 12" spacing for twice the beam depth at each end. Their length was approximated by 2.3 times the bottom flange width.

4.4.6 Mild Reinforcement - $0.45/lb

Two #6 bars were used for the entire length of the beam.

4.4.7 Additional Cost - $250/cy of girder

This additional cost was chosen to reflect labor, transportation, and construction costs of the alternate sections. It was calculated per cubic yard of girder to reflect the higher costs associated with larger beams. This cost was also used to make the total cost of most alternate

sections representative of their actual cost given in the surveys.

4.4.8 Total Cost

The total cost of each beam is taken as the sum of the above costs. This cost is then plotted as $/lf versus span length at girder spacing of 5, 8, and 10 feet. See Appendix E for details. This comparison provides a detailed analysis of which alternate sections are more cost effective than the AASHTO sections. It should be noted that it is most efficient to place girders at the largest practical girder spacing as has been suggested by Scott and Jacques (5,8).

4.5 Summary

In summary, this section included evaluating the structural efficiency and cost effectiveness of the alternate sections obtained in the first task of the research project. These alternate sections were then compared to the standard sections which Indiana is currently using. Comparisons were made using a structural efficiency factor, a computer program for structural evaluation, and

graphs showing cost effectiveness. The next chapter involves selecting the best beams in each span range for additional evaluation and recommending the final girders to be used in each span range.

CHAPTER 5: FINAL BEAMS AND RECOMMENDATIONS

5.1 Introduction

This task included selecting the best beams in each span range for additional evaluation. Selection was based on least relative material costs as well as comparing criteria influencing the production of these girders. Cross sections and properties of the selected beams were sent to several precasters to obtain comments on their production. Recommendations were then made for the final girders to be used in each span range.

5.2 Selection of Beams

Before selecting beams from the cost versus span length charts developed in Section 4.4 and shown in Appendix E, several constraints were determined. These constraints were specified with the assistance from the Indiana Department of Transportation and the regional office of FHWA. This included minimum web size, end blocks, and depth to span ratios. The minimum web size was selected as 6 or 7 inches. This eliminated any girder with a 5 inch web such as the

Colorado G68. A preference toward 7 inch webs was also sited by INDOT. End blocks were not used in the majority of the girders. Nor were they preferred by most survey participants. Comments from precasters in Section 5.4 were evaluated before eliminating any girders with end blocks. Beams with small depth to span ratios were eliminated from the final selection as recommended by INDOT. This included the Texas 54 and Colorado G68.

Considering the above constraints, the best beams in each span range were then selected from the cost versus span length charts developed in Section 4.4 and shown in Appendix E. The top three girders were first selected based on least material cost. The next two least cost girders were then chosen with a minimum 7 inch web. An INDOT Bulb Tee was also selected for comparison with the best beams in each span range. Appendix F shows the final girders which were selected in each span range. Also shown is the girder's ranking, cross sectional properties, and average strands and stirrups. The rank is based on relative material cost. For example, a rank of 2/24 denotes that the beam is the second cheapest out of 24 beams in this span range. The average strands and stirrups are based on an 8 foot girder spacing at the middle span in each range. For example, the average

strands and stirrups for an 80 foot span were used for the 70 - 90 foot span range.

5.3 Additional Analysis and Comparisons

Once the best beams were selected in each span range, further analysis and comparisons were made before recommending any of these sections. This involved evaluating parameters related to girder production by obtaining comments from precasters in Indiana and Kentucky. Precasters were sent cross sectional properties of the girders as well as reinforcement details. They were asked to compare the cost of producing these alternate sections against the standard AASHTO girders that Indiana is currently using. This included the use of end blocks if they are currently being used with the girder and formwork which was to be assumed standard. In addition, they were asked to comment on any advantages or disadvantages regarding ease of handling and transportation.

Comments received from precasters included recommendations on web sizes, rebar configurations, end blocks, slopes of bottom flanges, handling, and forms. Precasters noted problems with 6″ webs due to low slump concrete and reinforcement configurations. End blocks were

not recommended by precasters as they would require extra formwork and labor. One precaster stated that endblocks may double the cost of producing the girder. Precasters also noted problems with flat slope bottom flanges due to low slump concrete, and handling difficulties with thin top flanges. They also commented on the expense of creating new forms for each girder shape. Variable forms were preferred with the option of changing both web and depth dimensions.

5.4 Recommendations

Recommendations were made for the final girders to be used in each span range. This was based on the selection criteria stated in Sections 5.2 and 5.3 which consisted of least relative material costs as well as ease of production. Following are the recommendations in each span range. Detailed information on the final selection is listed in Appendix F.

5.4.1 30-50 Feet

The AASHTO I is ranked first out of 18 girders based on least relative material costs. The AASHTO II girder may

also be used in the upper portion of this span range. The alternate sections evaluated in this range were found to be less economical than the AASHTO sections. No alternate sections are therefore recommended in this span range.

5.4.2 50-70 Feet

The AASHTO III is ranked seventh out of 18 girders based on least relative material costs. The AASHTO II girder may also be used in the lower portion of this span range. Most of the alternate sections which were found to be more economical than the AASHTO sections had 6 inch webs. It is recommended that the AASHTO II and III continue to be used in this span range as no alternate sections provide sufficient savings.

5.4.3 70-90 Feet

The Illinois 54″ is ranked second out of 24 girders based on least relative material costs. The AASHTO IV girder may also be used in this span range although it ranked 16 out of 24. Significant savings would not result with the Washington 58G which is ranked first. Therefore it is

recommended that INDOT's current alternate section, the Illinois 54", be used in this span range.

5.4.4 90-110 Feet

The AASHTO V is ranked sixteenth out of 30 girders based on least relative material costs. Significant savings would therefore result by using alternate sections. The table shows six final girders to be more cost effective than the AASHTO V girder. The top three girders were not selected as they had 6 inch webs. The fourth, fifth, and sixth girders had similar costs. The Kentucky 66" was chosen as it had variable forms and is being produced by local precasters. It is therefore recommended as an alternate section for 90-110 feet.

5.4.5 110-130 Feet

The AASHTO VI is ranked nineteenth out of 21 girders based on least relative material costs. Significant savings would therefore result by using alternate sections. The table shows five final girders to be more cost effective than the AASHTO VI girder. The Kentucky 78" and 84" girders

with variable webs are ranked first, third, and fifth. They are therefore recommended as an alternate section for 110-130 feet. This would result in a savings of as much as 20 to 25 percent of the bridge superstructure as can be seen in Appendix J.

5.5 Summary

In summary, this section included selecting the best beams in each span range for additional evaluation. This selection was based on least relative material costs and criteria influencing the production of these girders. This included comments received from precasters in Indiana and Kentucky. No changes were recommended for the 30-90 span range. The Kentucky girders with variable webs and depths were recommended for the final girders to be used for the 90-130 foot span range. This would result in a savings of as much as 20 to 25 percent of the bridge superstructure. The next chapter explains the design aids created for the final girders and the standard AASHTO sections.

CHAPTER 6: DESIGN AIDS

6.1 Introduction

This task included preparing design aids for the final girders selected in Chapter 5 and the standard sections used by INDOT. The design aids were prepared for both simple and continuous spans as well as 6000 and 7000 psi girder concrete. They consist of three steps to select and design prestressed bridge girders. This includes choosing the appropriate girder for a given span range, and determining the required number and layout of prestressing strands.

6.2 Design Aid Analysis

Design aids were created in both SI and metric units to provide an initial prestressed bridge girder selection and design. They are not to be used as final designs, but are to be used as a starting point for the designers. Creation of the design aids was done by using the analysis section of the computer program, "PCBM," developed by Professor Robert H. Lee at Purdue University. This included provisions for simple and continuous spans, 6000 and 7000 psi girder

concrete, and number and layout of prestressing strands. Debonding of strands was also used to satisfy allowable stresses, but will not be shown in the design aids as it will have to be evaluated in the final design process. Also, the weight of intermediate diaphragms, the weight of permanent metal deck forms and the weight of composite loads, i.e. bridge railings, curbs or sidewalks, were not included in this study. These loads will have to be included in the final design process.

Computer runs at various continuous spans or with 7000 psi concrete showed an increase in span capabilities of between 5 and 10 feet when compared to simple spans or 6000 psi concrete. It was therefore decided to create the design aids with simple spans and 6000 psi concrete with a footnote stating that beam spans may increase 5 or 10 feet when using 7000 psi concrete or continuous spans. This was assumed adequate as the design aids are only an initial starting point for the designer and not a final design.

6.3 Step 1: Overall Girder Selection

The first step in the initial design process is to use the Prestressed Concrete I-Beam Selection Chart, found in Appendix G, to select the appropriate girder for a given

span and girder spacing. This chart shows the possible span ranges versus girder spacing for the AASHTO I-IV Series, Illinois 54″ and the Kentucky BT Series.

For additional information with regards to economy refer to Appendix J. This chart was created by plotting cost per square foot of deck against girder spans between 30 and 130 feet. It can therefore be used to compare the cost of girders for any width of bridge deck.

Appendix J shows two charts plotted for 30-130 feet. The AASHTO beams, Illinois 54″, and Kentucky sections are plotted at 5, 8, and 10 foot girder spacing. The legend is defined as the beam type followed by the girder spacing. For example, AAI-8 denotes the AASHTO I girder at 8′ spacing, while KY66-5 denotes the Kentucky 66″ girder at 5′ spacing. These two charts were then broken down into 4 smaller span ranges to show a more detailed view of the chart. Appendix J shows each of these charts plotted for 30-65 feet, 65-90 feet, 90-110 feet, and 110-130 feet.

6.4 Step 2: Design Aid

The second step in the initial design process is to determine the approximate number of strands required for the girder selected in Step 1. Design aids were created to show

the number of strands plotted against the girder spacing and span. These design aids are shown in Appendix H in both metric (SI) and inch-pound units.

6.5 Step 3: Design Table

The third step in the initial design process is to determine the strand layout for the number of prestressing strands selected in Step 2. The table shows the layout of the bottom prestressing strands as well as the top prestressing strands. The top strands were used to help control tensile stresses near or at the top ends of the girders. For conformity this was done for every girder analyzed, but the actual need of the top strands will have to be evaluated during final design. It also shows the maximum allowable span for the given number of prestressing strands. In addition, the table shows a cross section of the girder as well as relevant properties to aid in the initial design process. These design tables are shown in Appendix I. See the end of Appendix L for reinforcement details.

6.6 Summary

In summary, this task included preparing design aids for the final girders selected in this study as well as the AASHTO standard sections and Illinois 54". The design aids were prepared for simple and continuous spans, and 6000 and 7000 psi concrete. They consist of 3 steps to select and design prestressed bridge girders. This includes choosing the most appropriate and economical girder as well as the required number and layout of prestressing strands. The next chapter summarizes the general conclusions from the work in this study.

CHAPTER 7: SUMMARY AND CONCLUSIONS

7.1 Summary

The objective of this investigation was to evaluate feasible alternatives to the current standard AASHTO bridge girder sections used in the State of Indiana. This included precast pretensioned bridge girders for spans from 30 to 130 feet with girder spacing between 5 and 10 feet and up to 12 feet for the longer spans. Other criteria included girder design concrete compressive strengths up to 7000 psi, 8″ total concrete deck thickness with design strength of 4000 psi, grade 60 steel for slab reinforcement and stirrups, and 1/2″ special grade 270 low-relaxation strand for prestressing steel. Post-tensioning and pretensioned box girders were outside the scope of the study.

Approximately 100 alternate sections were received from surveys sent to various departments of transportation, consultants, and precasters in the United States. The girder cross sections were then evaluated for their structural efficiency and cost effectiveness. This was done using the computer program, PCBM, developed by Professor Robert H. Lee at Purdue University and currently used by INDOT. Local

precasters were then contacted to obtain further comments on the possible production of any of these girders.

7.2 Findings/Conclusions

The structural evaluation and cost effectiveness phase of this study was performed to recommend the best beams in each span range. Analysis showed the AASHTO I, II, & III girders to be economical for spans from 30 - 70 feet. No alternate sections were therefore recommended in this span range. The Illinois 54″ girder was found to be economical for spans from 70 - 90 feet. Therefore its continued use was recommended in this span range.

Alternate sections were found to be more economical for spans over 90 feet. The Kentucky 66″ Bulb Tee was recommended for spans between 90 - 110 feet. The Kentucky 78″ Bulb Tee was recommended for spans between 110 - 130 feet to provide considerable savings over the standard AASHTO girders. This would result in a savings of as much as 20 to 25 percent of the bridge superstructure as can be seen in Appendix J.

In general, structural evaluation of the alternate sections showed that bulb tees were more efficient than

standard I-Shaped girders. Spacing beams at the largest possible girder spacing was also found to be the most cost effective.

7.3 Recommendations

The research described in this report supports more efficient alternate sections for use in the State of Indiana as replacements for the current standard AASHTO sections. Results of the study showed that the Kentucky Bulb Tees would provide considerable savings over the standard AASHTO girders in spans from 90 to 130 feet. Their use is therefore recommended to the State of Indiana.

Design Aids were created for these Kentucky Bulb Tees as well as for the AASHTO standards. This was done in metric (SI) and inch-pound units to simplify design of the existing sections and implement design of the proposed Kentucky sections.

The Kentucky sections are currently being produced by local precasters in Kentucky. They have variable forms with webs from 6 to 8 inches and depths from 60 to 78 inches. Adopting these alternate sections would result in savings of as much as 20 to 25 percent of the bridge superstructure.

7.4 Future Work

As prestressed technology advances, there is an increasing need to continue research in the area of bridge girder sections. This research should concentrate on both advances in materials as well as advances in design procedures.

This study supports further research in these areas. Future studies should include the implementation of LRFD design for precast prestressed bridge girders, the use of higher strength concrete in bridge girders, as well as other special topics. These include lateral stability, the use of precast prestressed bridge panels, and increased top flanges for enhanced structural performance. Other research studies are also encouraged and recommended for increased economy in bridge construction.

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Appendix A

Survey Summary for Precast Prestressed Highway Girders

	Concrete						Reinf.		
	Deck $/sqft	Superstruc. $/sqf	Norm. $/cyd	Lt. Wt $/cyd	Forms $/ft	Strands $/ft	Black $/lb	Epoxy $/lb	Labor $/hr
CONSULTANTS									
Butler, Fairman & Seufert	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
RQAW & Associates	$13-$18	$40-$60	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sieco	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
American Consulting Eng. Bridge Dept.	$9.33-$12.60	$45-$65	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PRECASTERS									
Hydro Conduit Corp. W.L.	$9-$10	$38	$37	$46	N/A	N/A	N/A	N/A	$17.50
Henderson Hydro Cond Dennis Buttram	N/A	N/A	$42	N/A	$600	$0.17	$0.16	$0.25	$16.50
Prestress Services	N/A	N/A	$54	N/A	$25-$40 lft	$0.20	N/A	N/A	$3-$5 ft
UCP Bill Law	N/A	N/A	$31	N/A	$200-$400	$0.18	$0.21	$0.28	$13.50
Egyption Concrete Co.	N/A	N/A	N/A	N/A	$30 sq/ft	N/A	N/A	N/A	$16.70
Elk River Concrete	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
DOT									
Indiana	295 $/cyd	320 $/cyd	N/A	N/A	N/A	$0.30	$0.45	$0.55	N/A
Washington	N/A	$50 - $65	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Michigan	$25 - $30	$50 - $60	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Illinois	See Survey	See Survey	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wisconsin	N/A	$37	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Texas	$31.26	$18.46	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ohio	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Kentucky	$8	$34	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Florida	$8 - $11	$22 - $29	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Pennsylvania	$15	$40	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Virginia	N/A	$35	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Colorado	N/A	$29 - $66	N/A	N/A	N/A	N/A	N/A	N/A	N/A

N/A Information not available

Survey Summary for Precast Prestressed Highway Girders

	Common	Beam Properties					Lt. Wt Conc.		Deck		
	Spans ft	f'ci	f'c	max f'c	lb/cft	Strands*	f'c	lb/cft	f'c	lb/cft	Type
CONSULTANTS											
Butler, Fairman & Seufert	80-110	4500	5500	6000	150	.5" SLL	N/A	115	5000	150	8" conc.
RQAW & Associates	40-60	4000	5000	N/A	150	.5" LL	6000	130	N/A	N/A	conc.
Sieco	40-80	4000	5000	6000	145	.5" LL	N/A	N/A	N/A	N/A	conc.
American Consulting Eng. Bridge Dept.	70-100	4000	5000	7000	150	.5" SLL	N/A	110	N/A	N/A	8" conc.
PRECASTERS											
Hydro Conduit Corp. W.L.	40-80	4000-5500	7000	8000	142	.5" SLL-.375"SR	7-8	125	N/A	N/A	ALL
Henderson Hydro Cond Dennis Buttram	60-70	4000-5500	5000	6000	150	.5" LL	N/A	N/A	N/A	N/A	8" conc.
Prestress Services	70-140	4000-5000	5000-6000	N/A	150	.5" SLL & LL	N/A	130	N/A	N/A	8" conc.
UCP Bill Law	70-100	5000	5500	N/A	150	.5" SLL	N/A	130	N/A	N/A	8" conc.
Egyption Concrete Co.	60-70	4000	5000	7500	150	.5" SLL	No	N/A	N/A	N/A	8" conc.
Elk River Concrete	90-120	6000	7000	8000	155	.5" LL	No	N/A	4200	155	9" conc.
DOT											
Indiana	30-120	4000	5000	6500	150	.5" LL	7000	130	4000	150	8" conc.
Washington	90-120	4500	6000	7000	155	.5" LL	N/A	N/A	N/A	N/A	N/A
Michigan	N/A	3500	5000-7000	N/A	150	.5" LL	N/A	N/A	N/A	N/A	conc.
Illinois	N/A	5000	6000	6000	150	.5" LL	N/A	N/A	N/A	N/A	conc.
Wisconsin	ALL	N/A	6000	7000	155	.5" LL	N/A	N/A	4000	N/A	conc.
Texas	80-132	6400	6800	8000	150	.5" LL	N/A	N/A	N/A	N/A	conc.
Ohio	60-90	4000	5500	N/A	145	.5" LL	No	N/A	4500	N/A	conc.
Kentucky	70-100	4000-5500	5000-7000	7000	150	.5" LL	7000	semi	4000	N/A	conc.
Florida	70-100	4000-5500	5000-6500	6500	150	.5" SLL & LL	No	N/A	4500-5500	N/A	conc.
Pennsylvania	55-80	5500-7200	6500-8000	8000	150	.5" LL	N/A	115	4000	N/A	conc.
Virginia	55-100	4000	6000	6000	150	.5" .375"SR LL	4000	N/A	4000	N/A	conc.
Colorado	90-145	4000-6500	4000-8500	8500	150	.5" LL	No	N/A	4500	N/A	conc.

*LL Lo-Lax Strands
*SLL Special Lo-Lax Strands
*SR Stress Relieved Strands
N/A Information not available
All Concrete Strengths in psi

Survey Summary for Precast Prestressed Highway Girders

CONSULTANTS	Live Load	Draping vs. Debonding	End Splitting # of Bars	Cost of Beam Type $/lft*					
Butler, Fairman & Seufert	HS20	N/A	# 5 @ the ends	N/A	N/A	N/A	N/A	N/A	N/A
RQAW & Associates	HS20	N/A	N/A	I-50	II-55	III-60	IV-85	V-105	N/A
Sieco	HS20	N/A	AASHTO Std's	N/A	N/A	N/A	N/A	N/A	N/A
American Consulting Eng. Bridge Dept.	HS20	N/A	Detensioning	I-45-50	II-60-65	III-80	?	?	N/A

PRECASTERS	Live Load	Draping vs. Debonding	End Splitting # of Bars	Cost of Beam Type $/lft*					
Hydro Conduit Corp. W.L.	HS20-25	Debonding	3/4" Straps	I-41	II-51	III-56	IV-60	V-75	BT74"-90
Henderson Hydro Cond Dennis Buttram	HS25	Debonding & Draping	#4 @ 3" for 2'	N/A	II-40-45	III-60	IV-68-75	66"-90	N/A
Prestress Services	HS25	Debonding & Draping	#4 @ 3" for 2'	N/A	N/A	N/A	N/A	N/A	N/A
UCP Bill Law	HS25	Debonding & Draping	#3 @ 3" for 2'	N/A	II-40-50	III-50-60	IV-60-66	MOD IV 70-75	N/A
Egyption Concrete Co.	HS20-25	Draping	Sole Plates	N/A	N/A	N/A	N/A	N/A	N/A
Elk River Concrete	HS25	Draping	AASHTO Std's	N/A	N/A	N/A	N/A	N/A	N/A

DOT	Live Load	Draping vs. Debonding	End Splitting # of Bars	Cost of Beam Type $/lft*					
Indiana	HS20	Debonding	3/4" Straps	AAI - $58	AAII - $59	AAIII - $67	AAIV - $76	AAV - $95	N/A
Washington	HS25	N/A	N/A	W24G- $70 to W74G- $90					N/A
Michigan	HS20-25	Draping	#3 @ 1'-3"	AAI - $52	AAII - $63	AAIII - $73	AAIV - $91	WIS $70 - $105	N/A
Illinois	HS20	Draping	#3/AASHTO	36"- $61.74	42"-66.08	48"- $68.43	54"- $72.73	63"- $80.00	72"- $105.06
Wisconsin	HS20	Draping	N/A	$55 to $90					N/A
Texas	HS20	N/A	AASHTO 9.21.3	A- $39.60	B- $43.36	C- $45.48	54"- $49.96	IV- $45.77	U54- $55.00
Ohio	HS20	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Kentucky	HS25	N/A	AASHTO 9.21.3	AAII- $70	AAIII- $75	AAIV- $85	60-84" $110- $165		
Florida	HS20	N/A	#3 @ 6"	AAII - $55	AAIII - $62	AAIV - $77	AAV - $95	AAVI - $99	FBT - $100
Pennsylvania	HS25	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Virginia	HS20-25	N/A	AASHTO 9.21.3	N/A	N/A	N/A	N/A	N/A	N/A
Colorado	HS20	N/A	AASHTO 9.21.3	$70 to $100					

*AAI - $50 AASHTO Type I Costs 50 $/lft
*BT74 Bulb Tee 74"
*W24G Washington 24" Beam
*WIS70 Wisconsin 70" Beam

*36" Illinois 36" Beam
N/A Information not available
A- $39.60 Texas Type A

SURVEYS MAILED AND RECEIVED

PRECASTERS:

* Hydro Conduit (Lafayette, Indiana)
Prestress Services (Decatur, Indiana)
* Hydro Conduit (Henderson, Kentucky)
* Prestress Services (Lexington, Kentucky)
* Essroc (Melbourne, Kentucky)
* Egyptian Concrete Company (Salem, Il)
Illinois Concrete Company (Champaign, Il)
Prestress Engineering Corporation (Algonquin, Il)
Price Brothers-Midwest Inc. (Rochelle, Il)
Spancrete of Illinois (Crystal Lake, Il)
County Prestress Corp. (Eau Claire, WI)
Spancrete Inc. (Greenbay, WI)
Spancrete Inc. (Waukesha, WI)
Premarc Corp. (Grand Rapids, MI)
Superior Products (Taylor, MI)
Marietta Structures Corp. (Marietta, OH)
* United Precast Inc. (Mt. Vernon, OH)
* Elk River Concrete (Maple Grove, Minnesota)

CONTRACTOR:

Rieth-Riley Construction (Goshen, Indiana).

CONSULTANTS:

* American Consulting Engineers (Indianapolis)
* Butler, Fairman & Seufert (Indianapolis)
HNTB (Indianapolis)
* RQAW & Assoc. (Indianapolis)
SEG Engineers (Indianapolis)
* SIECO (Columbus, IN)
United Consulting Engineers (Indianapolis)

DEPARTMENTS OF TRANSPORTATION:

* Indiana
* Florida
* Illinois
* Kentucky
* Michigan
* Washington
* Texas
* Wisconsin
* Ohio
* Pennsylvania
* Virginia
* Colorado

* Denotes survey has been received

Survey of Current Use of Precast Prestressed AASHTO & Alternate Bridge Girder Sections
(Not including Box Beams)
for Precasters

Design and Construction Details

1. For pretensioning applications, which alternate prestressed concrete girder sections are being used in addition to or instead of the current standard AASHTO I-beam sections? (Also please enclose cross section details of these alternate sections.)

   What are their advantages?

2. Which AASHTO & Alternate prestressed concrete girders are being used for the following spans?

   30-45'
   40-60'
   55-80'
   70-100'
   90-120'

   Which bridge span range is the most common?

3. When were these alternate sections first used?

4. Which alternate sections would be preferred if made available?

5. What work is presently being done to modify or improve current I-beam sections?

6. What is the longest span built using single pretensioned girders? (not grouped or spliced)

7. Are end blocks required? If so, when are they used?

8. How is bursting (end splitting) reinforcement designed?

9. Is tension in concrete under service load permitted? If so, how much?

10. Which concrete strengths are being utilized? What is the strength at release (f'ci) and the 28 day strength (f'c) for typical pretensioned beam designs? What is the maximum 28 day strength (f'c) that a beam designer is allowed to use?

11. What is the weight per cubic foot of the concrete that is utilized?

12. Is lightweight or semi-lightweight concrete being used for bridge girders or decks? If so, what is the 28 day strength and weight per cubic foot?

13. What are the size and grade of prestressing strands being utilized? Are stress-relieved and low-relaxation strands both utilized?

14. What is the maximum girder spacing for pretensioning applications?

15. Are interior diaphragms used? If so, what is the criteria for their spacing?

16. What types of decks are being used with the prestressed girders? If concrete decks are used, what is the concrete design strength?

17. Are stay in place forms being used for concrete decks?

18. What standard highway live loads are the bridge girders designed for? (HS20 or HS25)

19. Are girder design aids for bridge designers available?

<u>Fabrication Details</u>

1. What is the minimum spacing between strands? Is draping or debonding of strands used?

2. Are epoxy coated strands and mild reinforcement being used?

3. What is the minimum concrete cover?

4. What is the limitation on web thickness?

5. What are the restrictions on draping locations?

6. How many precasting plants are in the State?

7. What out of State plants are utilized?

8. What is the normal turn around time for prestressing beds?

9. Are there any new developments in prestressing hardware systems?

Transportation Requirements and Restrictions

1. What is the maximum girder length allowed with and without a permit?

2. What is the maximum girder weight allowed with and without a permit?

3. What is the availability of moving equipment in the yard and on the road?

4. Are there instability problems during transportation and erection?

Availability and Costs

1. What is the cost in place per linear foot of each girder section?

2. What is the cost variation due to concrete strength?

3. How do girder fabrication costs vary for each type of bridge girder fabricated?

   concrete ($/cy)
   strands (c/ft)
   reinforcement (c/lb)

4. What would new forms cost?

5. What are the average labor costs?

6. What could be done to cut down on costs?

7. What are the current hauling costs? ($/kip/mile)

8. What are the State unit prices for cost estimates?

9. What are the availability, capacity and costs for cranes at the plant?

Additional Information

Any additional information or comments would be appreciated. Also please enclose drawings of I-beam or girder sections and design aids if available.

Survey of Current Use of Precast Prestressed AASHTO & Alternate Bridge Girder Sections
(Not including Box Beams)
for Consultants

Design and Construction Details

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17. Are stay in place forms being used for concrete decks?

18. What standard highway live loads are the bridge girders designed for? (HS20 or HS25)

19. Are girder design aids for bridge designers available?

Transportation Requirements and Restrictions

1. What is the maximum girder length allowed with and without a permit?

2. What is the maximum girder weight allowed with and without a permit?

3. What is the availability of moving equipment?

4. Are there instability problems during transportation?

Structural Durability

1. What is the average design life span?
2. What is the frequency of inspection?
3. What problems are generally encountered?
4. Are cracks found in prestressed concrete girders?

Availability and Costs

1. What is the cost in place per linear foot of each girder section?
2. What is the cost in place per square foot of deck?
3. What is the cost per square foot of superstructure?

Additional Information

Any additional information or comments would be appreciated. Also please enclose drawings of I-beam or girder sections and design aids if available.

Survey of Current Use of Precast Prestressed AASHTO & Alternate Bridge Girder Sections
(Not including Box Beams)
for State

Design and Construction Details

1. For pretensioning applications, which alternate prestressed concrete girder sections are being used in addition to or instead of the current standard AASHTO I-beam sections? (Also please enclose cross section details of these alternate sections.)

   What are their advantages?

2. Which AASHTO & Alternate prestressed concrete girders are being used for the following spans?

   30-45'
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   55-80'
   70-100'
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19. Are girder design aids for bridge designers available?

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1. What is the maximum girder length allowed with and without a permit?

2. What is the maximum girder weight allowed with and without a permit?

3. What is the availability of moving equipment?

4. Are there instability problems during transportation?

Structural Durability

1. What is the average design life span?

2. What is the frequency of inspection?

3. What problems are generally encountered?

4. Are cracks found in prestressed concrete girders?

Availability and Costs

1. What is the cost in place per linear foot of each girder section?

2. What is the cost in place per square foot of deck?

3. What is the cost per square foot of superstructure?

Additional Information

Any additional information or comments would be appreciated. Also please enclose drawings of I-beam or girder sections and design aids if available.

Appendix B

BEAM TYPES	SPANS (ft)	RECEIVED FROM	HEIGHT	TOP FLANGE	BOT FLANGE	WEB
Texas A	30-50	Texas DOT	28	12	16	6
Texas B	45-65		34	12	18	6.5
Texas C	65-85		40	14	22	7
Texas 54	75-95		54	16	16	6
Texas 72	115-135		72	22	22	7
Missouri 2	35-55	Egyption Concrete Illinois	32	13	17	6
Missouri 3	50-70		39	13	17	6
Missouri 4	60-80		45	13	17	6
Missouri 6	95-115		54	24	24	6.5
Florida BT 54	70-90	Florida DOT	54	48	30	6.5
Florida BT 63	90-110		63	48	30	6.5
Florida BT 72	110-130		72	48	30	6.5
Colorado BT 42	60-80	Colorado DOT	42	43	27	7
Colorado G 54	65-85		54	28	24	6
Colorado G 68	80-100		68	28	24	5
Colorado BT 72	95-115		72	43	27	7
Colorado BT 84	110-130		84	43	27	7
Minnesota 28M	30-50	Elk River Concrete Minnesota	28	12	18	6
Minnesota 36	30-50		36	12	18	6
Minnesota 40	50-70		40	16	22	6
Minnesota 45	50-70		45	30	26	6
Minnesota 54M	70-90		54	30	26	6
Minnesota 63	70-90		63	30	26	6
Minnesota 72	90-110		72	30	26	6
Minnesota 81	110-130		81	30	26	6

BEAM TYPES	SPANS (ft)	RECEIVED FROM	HEIGHT	TOP FLANGE	BOT FLANGE	WEB
W35DG	30-45	Washington State DOT	35	72 max	25	6
W53DG	40-60		53	72 max	25	6
W42G	40-60		42	15	20	6
W50G	55-80		50	20	25	6
W58G	70-115		58	25	25	6
W74G	90-110		73.5	43	25	6
Wisconsin 70"	90-115	Michigan DOT	70	30	26	6
Ill. 36"	30-60	Illinois DOT	36	12	18	6
Ill. 42"	40-80		42	16	22	6
Ill. 48"	55-100		48	18	22	7.5
Ill. 54"	70-120		54	20	22	6
PCI 54" Bulb Tee	70-120		54	42	26	6
PCI 63" Bulb Tee	90-120		63	42	26	6
PCI 72" Bulb Tee	90-120		72	42	26	6
AASHTO I	30-50	Indiana DOT	28	12	16	6
AASHTO II	40-60		36	12	18	6
AASHTO III	55-80		45	16	22	7
AASHTO IV	70-90		54	20	26	8
AASHTO V	90-110		72	20	26	8
AASHTO-PCI V	90-110		63	42	28	8
AASHTO-PCI VI	110-130		72	42	28	8
MOD AASHTO IV	70-90	Indiana DOT	54	18	24	6
MOD AASHTO V	90-110		63	40	26	6
MOD AASHTO VI	110-130		72	40	26	6

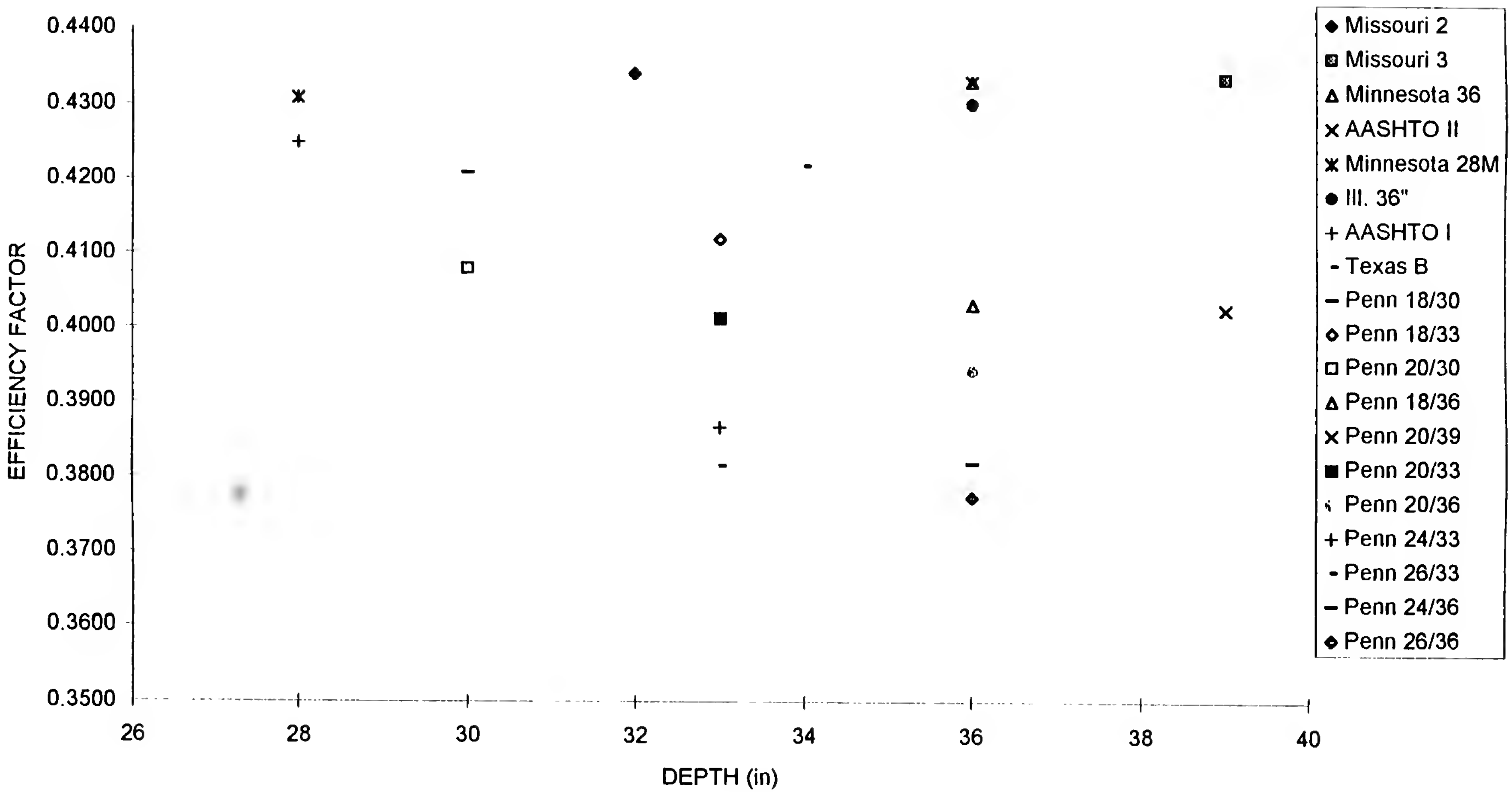
BEAM TYPES	SPANS (ft)	RECEIVED FROM	HEIGHT	TOP FLANGE	BOT FLANGE	WEB
BT 54 3'-6" Top	70-90	Indiana DOT	54	42	25	7
BT 54 4'-0" Top	70-90		54	48	25	7
BT 63 4'-0" Top	90-110		63	48	25	7
BT 63 4'-6" Top	90-110		63	54	25	7
BT 72 4'-6" Top	110-130		72	54	25	7
BT 72 5'-0" Top	110-130		72	60	25	7
Mod. IV 1'-8" top	70-100	Butler, Fairman & Seufert	54	20	22	6
Mod. IV 2'-2" top	70-100		60	26	22	6
Mod. IV 4' top	70-100		54	48	22	7
60" w/ 6" web	90-110	Kentucky DOT	60	34	24	6
66" w/ 6" web	105-125		66	34	24	6
72" w/ 6" web	120-140		72	34	24	6
78" w/ 6" web	120-140		78	34	24	6
84" w/ 6" web	120-140		84	34	24	6
90" w/ 6" web	120-140		90	34	24	6
60" w/ 7" web	90-110		60	35	25	7
66" w/ 7" web	105-125		66	35	25	7
72" w/ 7" web	120-140		72	35	25	7
78" w/ 7" web	120-140		78	35	25	7
84" w/ 7" web	120-140		84	35	25	7
90" w/ 7" web	120-140		90	35	25	7
60" w/ 8" web	90-110		60	36	26	8
66" w/ 8" web	105-125		66	36	26	8
72" w/ 8" web	120-140		72	36	26	8
78" w/ 8" web	120-140		78	36	26	8
84" w/ 8" web	120-140		84	36	26	8
90" w/ 8" web	120-140		90	36	26	8

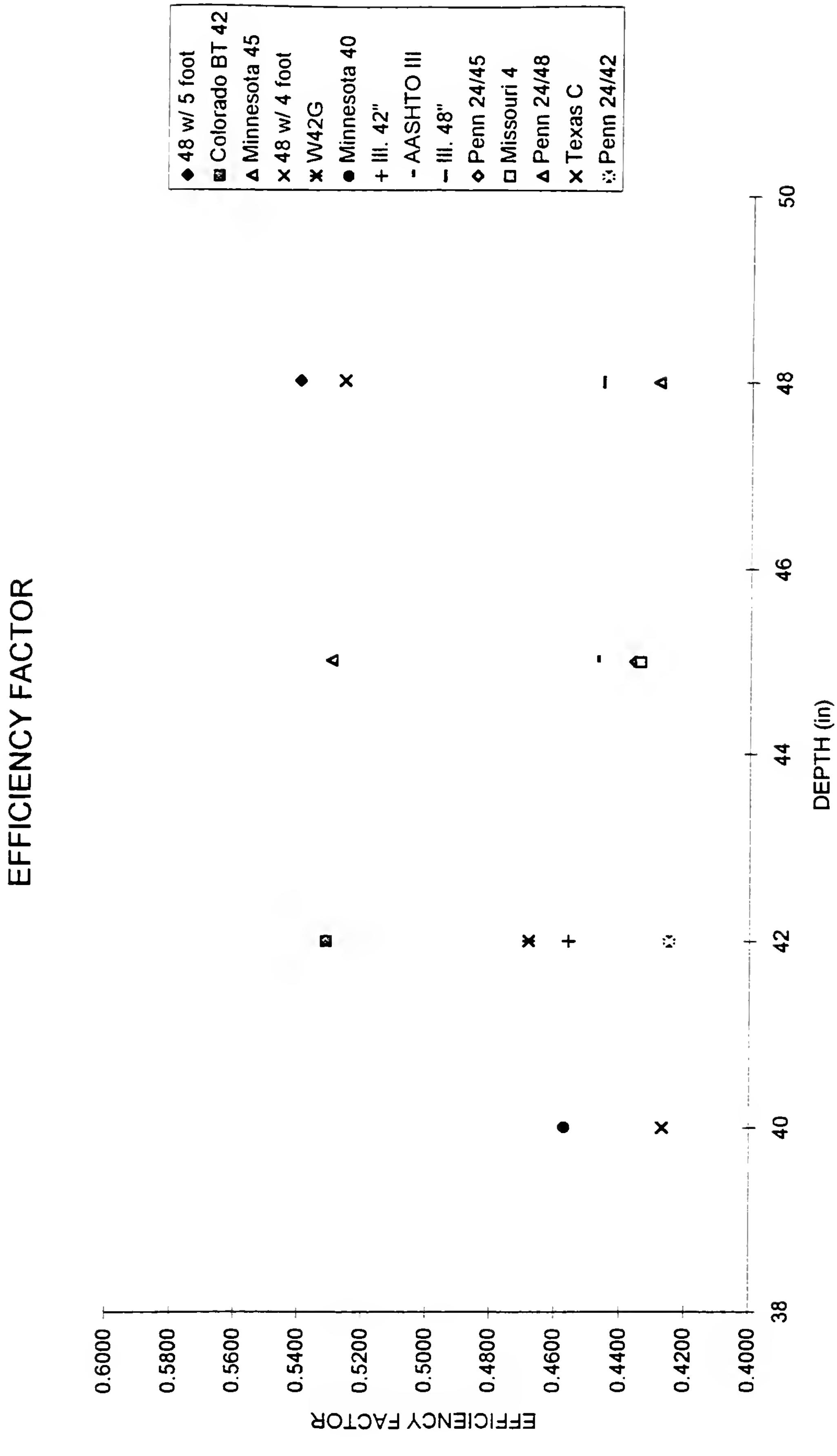
BEAM TYPES	SPANS (ft)	RECEIVED FROM	HEIGHT	TOP FLANGE	BOT FLANGE	WEB
48 w/ 4 foot	60-80	Prestress Services Lexington, Kentucky	48	48	25	7
54 w/ 4 foot	80-100		54	48	25	7
60 w/ 4 foot	90-110		60	48	25	7
66 w/ 4 foot	105-125		66	48	25	7
72 w/ 4 foot	120-140		72	48	25	7
78 w/ 4 foot	120-140		78	48	25	7
84 w/ 4 foot	120-140		84	48	25	7
48 w/ 5 foot	60-80		48	60	25	7
54 w/ 5 foot	80-100		54	60	25	7
60 w/ 5 foot	90-110		60	60	25	7
66 w/ 5 foot	105-125		66	60	25	7
72 w/ 5 foot	120-140		72	60	25	7
78 w/ 5 foot	120-140		78	60	25	7
84 w/ 5 foot	120-140		84	60	25	7

BEAM TYPES	SPANS (ft)	RECEIVED FROM	HEIGHT	TOP FLANGE	BOT FLANGE	WEB
18/30	30-50	Pennsylvania DOT	30	12	18	6
20/30	30-50		30	14	20	8
18/33	40-60		33	12	18	6
20/33	40-60		33	14	20	8
24/33	40-60		33	18	24	12
26/33	40-60		33	20	26	14
18/36	50-70		36	12	18	6
20/36	50-70		36	14	20	8
24/36	50-70		36	18	24	12
26/36	50-70		36	20	26	14
20/39	60-80		39	14	20	8
24/42	60-80		42	28	24	8
24/45	60-80		45	18	24	8
24/48	60-80		48	18	24	8
24/51	70-90		51	18	24	8
24/54	70-90		54	18	24	8
24/60	90-110		60	24	24	8
26/60	90-110		60	26	26	10
24/63	100-120		63	24	24	8
26/63	100-120		63	26	26	10

Appendix C

EFFICIENCY FACTOR

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EFFICIENCY FACTOR
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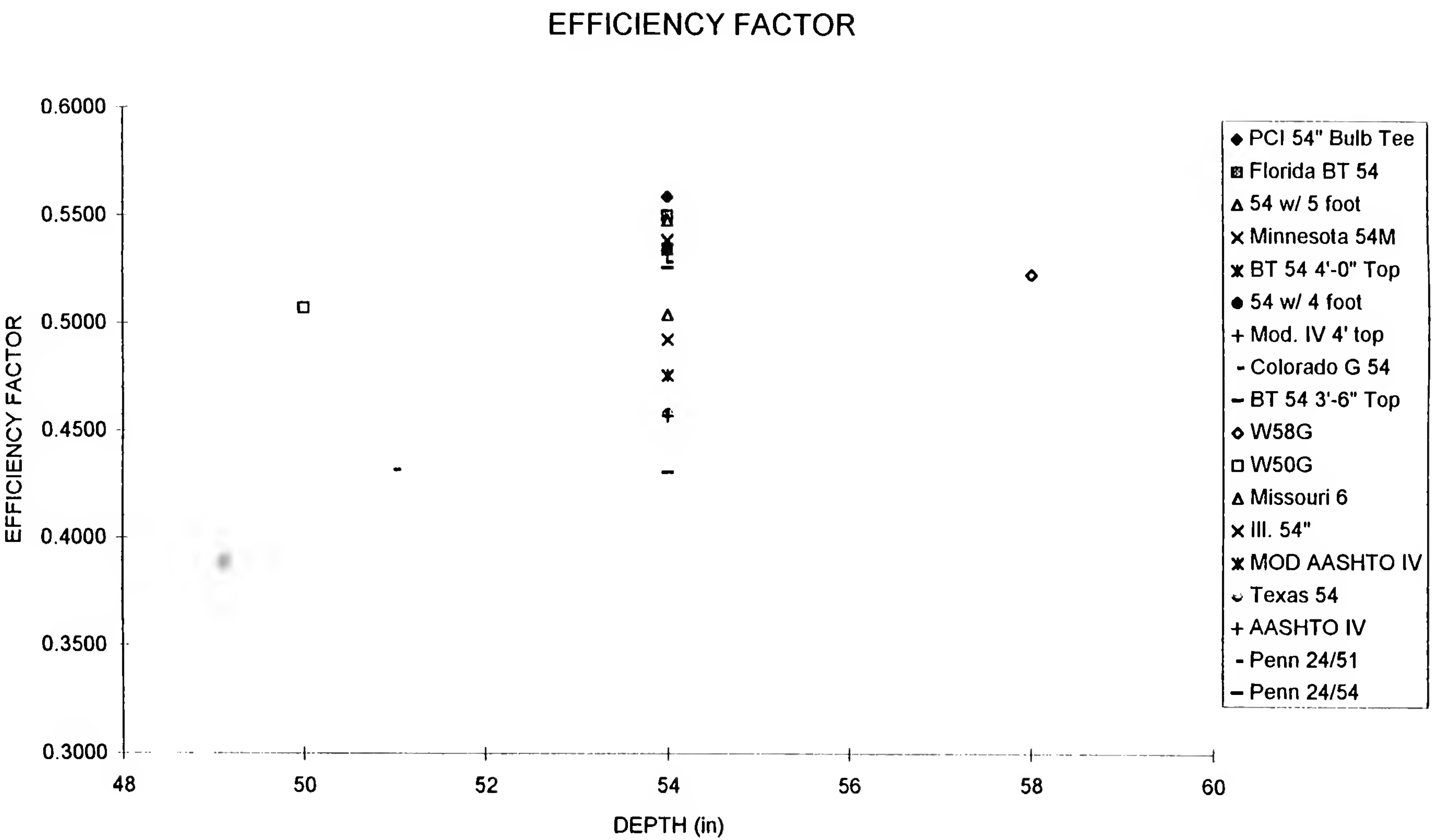
0.4400
0.4600
0.4800
0.5000
0.5200
0.5400
0.5600
0.5800
0.6000
38
40
42
44
46
48
50
DEPTH (in)
48 w/ 5 foot
Colorado BT 42
Minnesota 45
48 w/ 4 foot
W42G
Minnesota 40
Ill. 42"
AASHTO III
Ill. 48"
Penn 24/45
Missouri 4
Penn 24/48
Texas C
Penn 24/42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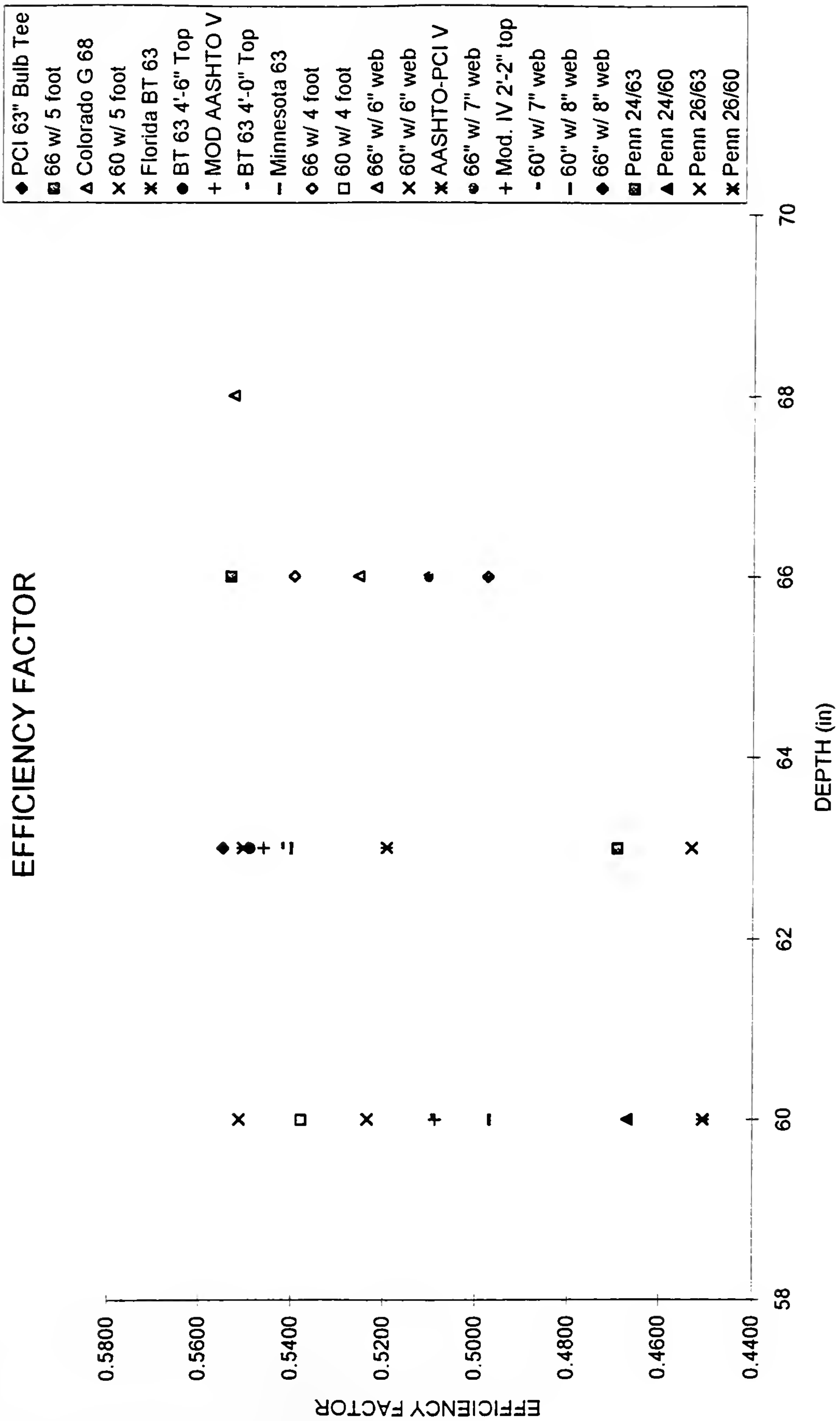
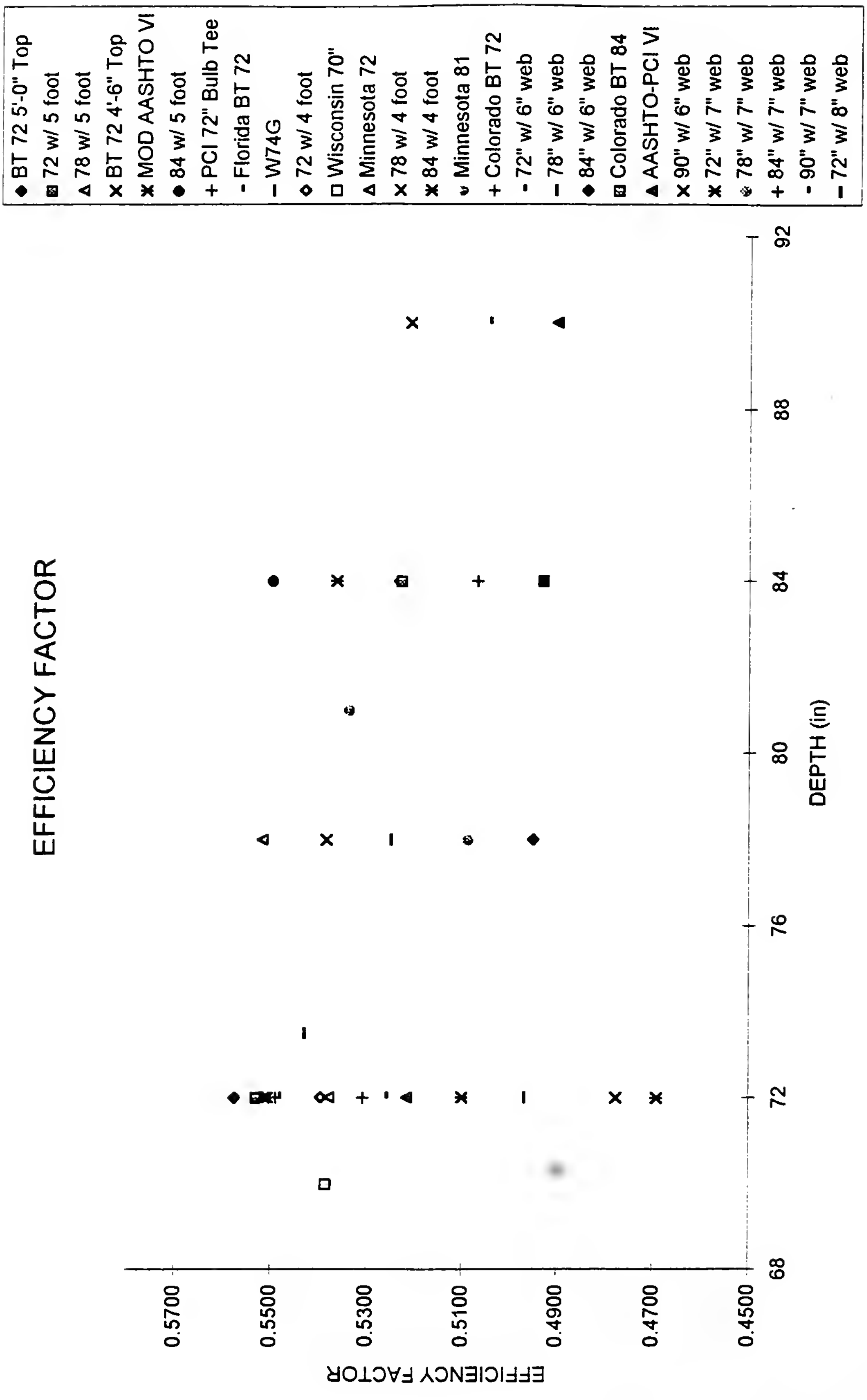
EFFICIENCY FACTOR
0.6000
0.5500
0.5000
0.4500
0.4000
0.3500
0.3000
48
50
52
54
56
58
60
DEPTH (in)
PCI 54" Bulb Tee
Florida BT 54
54 w/ 5 foot
Minnesota 54M
BT 54 4'-0" Top
54 w/ 4 foot
Mod. IV 4' top
Colorado G 54
BT 54 3'-6" Top
W58G
W50G
Missouri 6
Ill. 54"
MOD AASHTO IV
Texas 54
AASHTO IV
Penn 24/51
Penn 24/54


EFFICIENCY FACTOR
EFFICIENCY FACTOR
DEPTH (in)
0.5800
0.5600
0.5400
0.5200
0.5000
0.4800
0.4600
0.4400
58
60
62
64
66
68
70
PCI 63" Bulb Tee
66 w/ 5 foot
Colorado G 68
60 w/ 5 foot
Florida BT 63
BT 63 4'-6" Top
MOD AASHTO V
BT 63 4'-0" Top
Minnesota 63
66 w/ 4 foot
60 w/ 4 foot
66" w/ 6" web
60" w/ 6" web
AASHTO-PCI V
66" w/ 7" web
Mod. IV 2'-2" top
60" w/ 7" web
60" w/ 8" web
66" w/ 8" web
Penn 24/63
Penn 24/60
Penn 26/63
Penn 26/60



EFFICIENCY FACTOR
EFFICIENCY FACTOR
0.4500
0.4700
0.4900
0.5100
0.5300
0.5500
0.5700
DEPTH (in)
68
72
76
80
84
88
92
BT 72 5'-0" Top
72 w/ 5 foot
78 w/ 5 foot
BT 72 4'-6" Top
MOD AASHTO VI
84 w/ 5 foot
PCI 72" Bulb Tee
Florida BT 72
W74G
72 w/ 4 foot
Wisconsin 70"
Minnesota 72
78 w/ 4 foot
84 w/ 4 foot
Minnesota 81
Colorado BT 72
72" w/ 6" web
78" w/ 6" web
84" w/ 6" web
Colorado BT 84
AASHTO-PCI VI
90" w/ 6" web
72" w/ 7" web
78" w/ 7" web
84" w/ 7" web
90" w/ 7" web
72" w/ 8" web

Appendix D

BAR SIZE	SPA. (IN.)	Slab thickness (in.) / Effective span (ft.) — scale 0, 6, 7, 16
#6	5	
	$5\frac{1}{2}$	
	6	
	$6\frac{1}{2}$	
	7	
#5	5	
	$5\frac{1}{2}$	
	6	
	$6\frac{1}{2}$	←
	7	← 8 / 9.69; 8.25 / 9.89
	$7\frac{1}{2}$	← 8 / 9.50; 8.25 / 9.70; 8.5 / 9.91
	8	← 8 / 9.33; 8.25 / 9.54; 8.5 / 9.74; 8.75 / 9.94; 9 / 10.

0 6 7

DESIGN DATA

1992 AASHTO Standard Specifications for Highway Bridges (Load Factor Design)

f'_c = 4,000 psi (Class C Concrete)
f_y = 60,000 psi

HS20 Live Load + Impact
L.L. + Impact Moment Formula:

$$\frac{(S + 2)}{32} (P_{20}) (0.8) (1.3) \quad \text{(Kip-ft)}$$

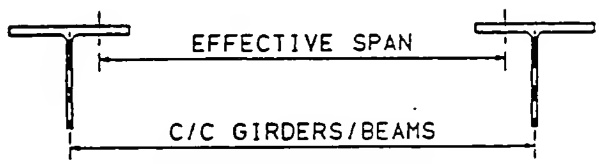
$$= \frac{(S + 2)}{32} (16) (0.8) (1.3) \quad \text{(Kip-ft)}$$

$$= (0.52)\, S + 1.04 \quad \text{(Kip-ft)}$$

Where S = Effective Span

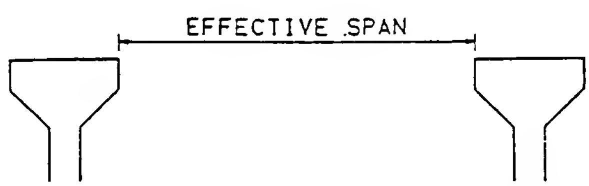
Allows for:

- 1 1/2 inches Wearing Surface
- 1 inch Cover
- 35 psf Future Wearing Surface
- 15 psf Permanent Metal Forms



Effective Span (S) =
c/c Girders/Beams - 1/2 Flange Width

STEEL STRUCTURES



Effective Span (S) = Clear Span

CONCRETE STRUCTURES

CONTINUOUS FLOOR SLAB DESIGN CHART

Attachment to Bridge Design Memorandum #246, October 1, 199?

EFFECTIVE SPAN IN FEET (0, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16)

BAR SIZE	SPA. (IN.)	8	8.25	8.5	8.75	9
#6	5	12.60	12.80	13.00	13.21	13.41
#6	$5\frac{1}{2}$	12.07	12.28	12.48	12.69	12.89
#6	6	11.63	11.84	12.04	12.25	12.45
#6	$6\frac{1}{2}$	11.27	11.47	11.67	11.88	12.08
#6	7	10.95	11.15	11.36	11.56	11.77
#5	5	10.83	11.04	11.24	11.45	11.65
#5	$5\frac{1}{2}$	10.47	10.67	10.88	11.08	11.29
#5	6	10.17	10.37	10.57	10.78	10.98
#5	$6\frac{1}{2}$	9.91	10.11	10.32	10.52	10.73
#5	7	9.69	9.89	10.10	10.30	10.51
#5	$7\frac{1}{2}$	9.50	9.70	9.91	10.11	10.32
#5	8	9.33	9.54	9.74	9.94	10.15

EFFECTIVE SPAN IN FEET (0, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15)

SLAB THICKNESS (IN.)
EST. COST PER SQ. FT. *

* The estimated cost includes concrete at $265/cyd and both transverse and longitudinal epoxy-coated reinforcing steel at $0.64/lb.

DESIGN DATA

1992 AASHTO Standard Specifications for Highway Bridges (Load Factor Design)

f'_c = 4,000 psi (Class C Concrete)
f_y = 60,000 psi

HS20 Live Load + Impact
L.L. + Impact Moment Formula:

$$\frac{(S+2)}{32}(P_{20})(0.8)(1.3) \quad \text{(Kip-ft)}$$

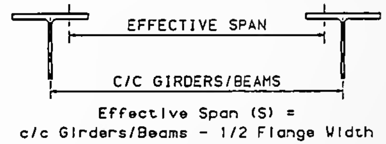
$$= \frac{(S+2)}{32}(16)(0.8)(1.3) \quad \text{(Kip-ft)}$$

$$= (0.52)\,S + 1.04 \quad \text{(Kip-ft)}$$

Where S = Effective Span

Allows for:

- 1 1/2 inches Wearing Surface
- 1 inch Cover
- 35 psf Future Wearing Surface
- 15 psf Permanent Metal Forms



Effective Span (S) =
c/c Girders/Beams - 1/2 Flange Width

STEEL STRUCTURES

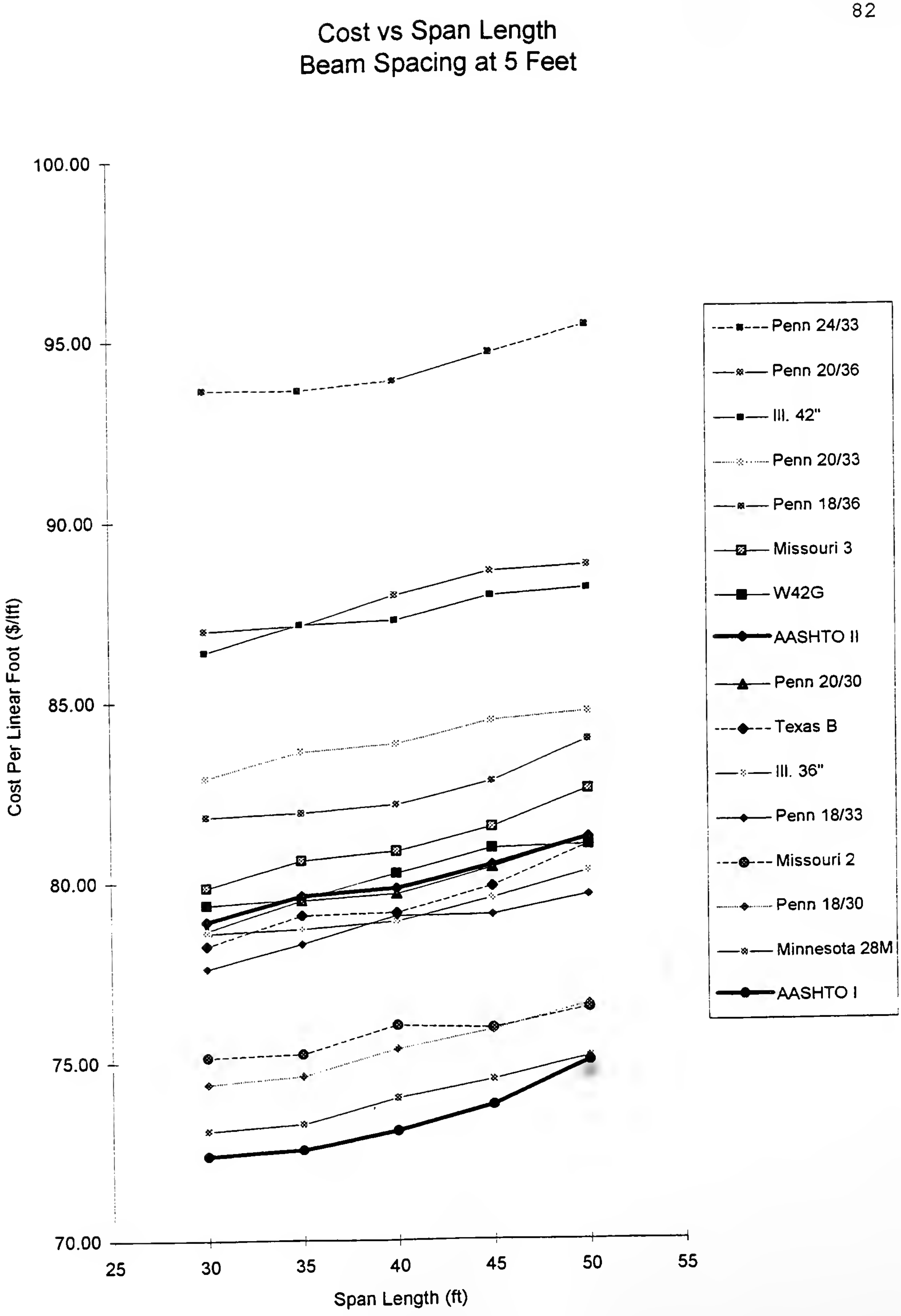
Effective Span (S) = Clear Span

CONCRETE STRUCTURES

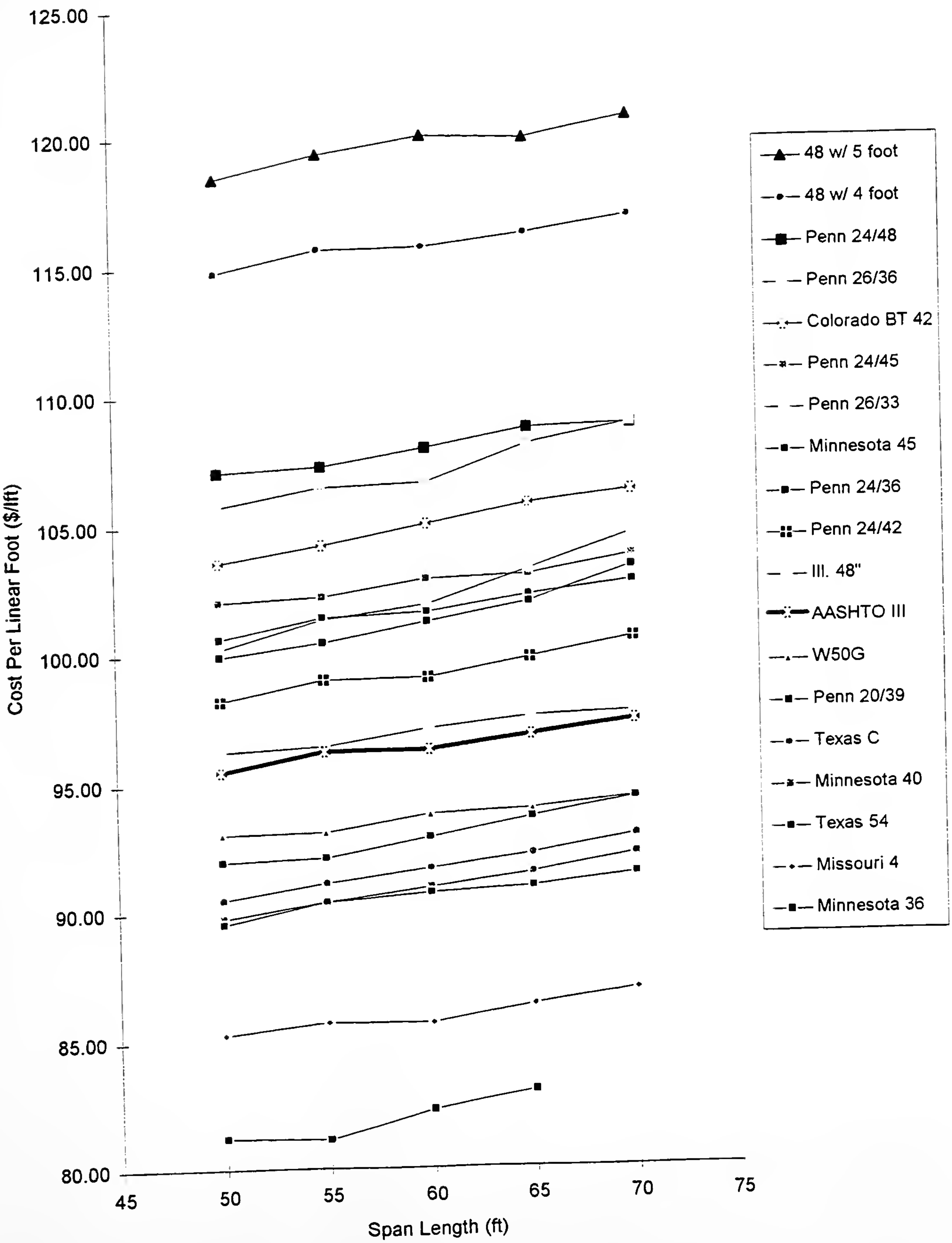
CONTINUOUS FLOOR SLAB DESIGN CHART

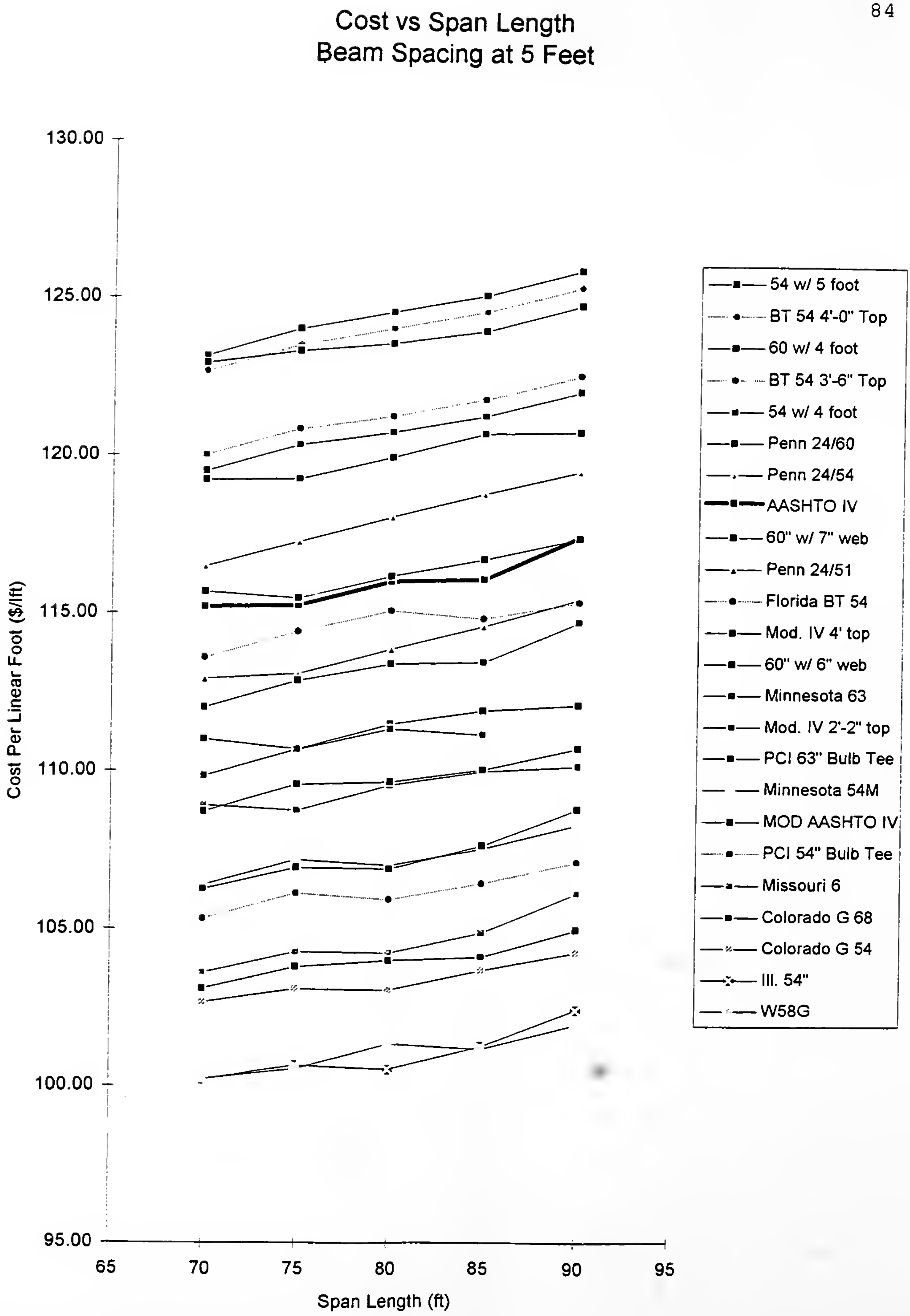
Attachment to Bridge Design Memorandum #246, October 1, 199?

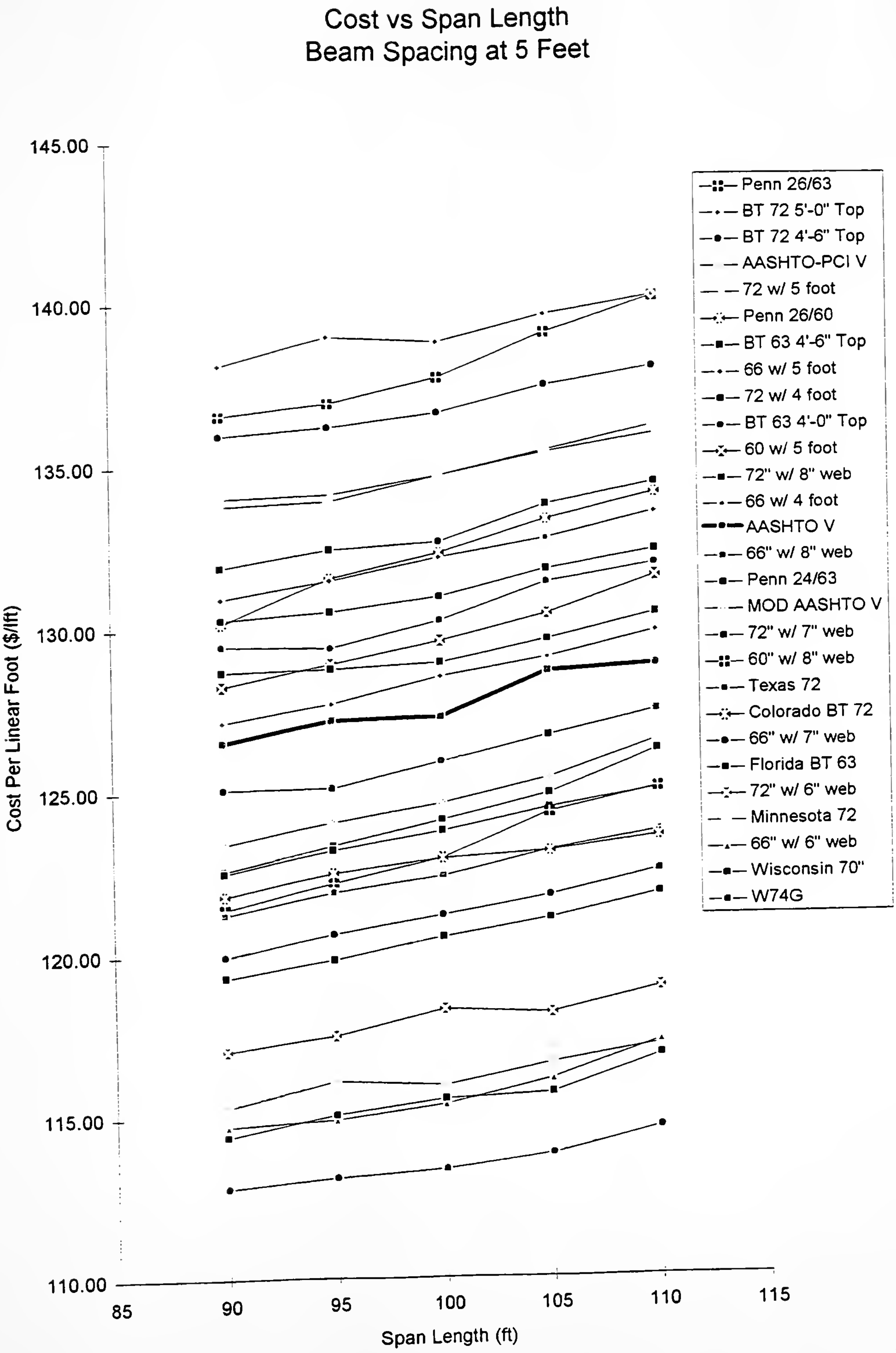
Appendix E

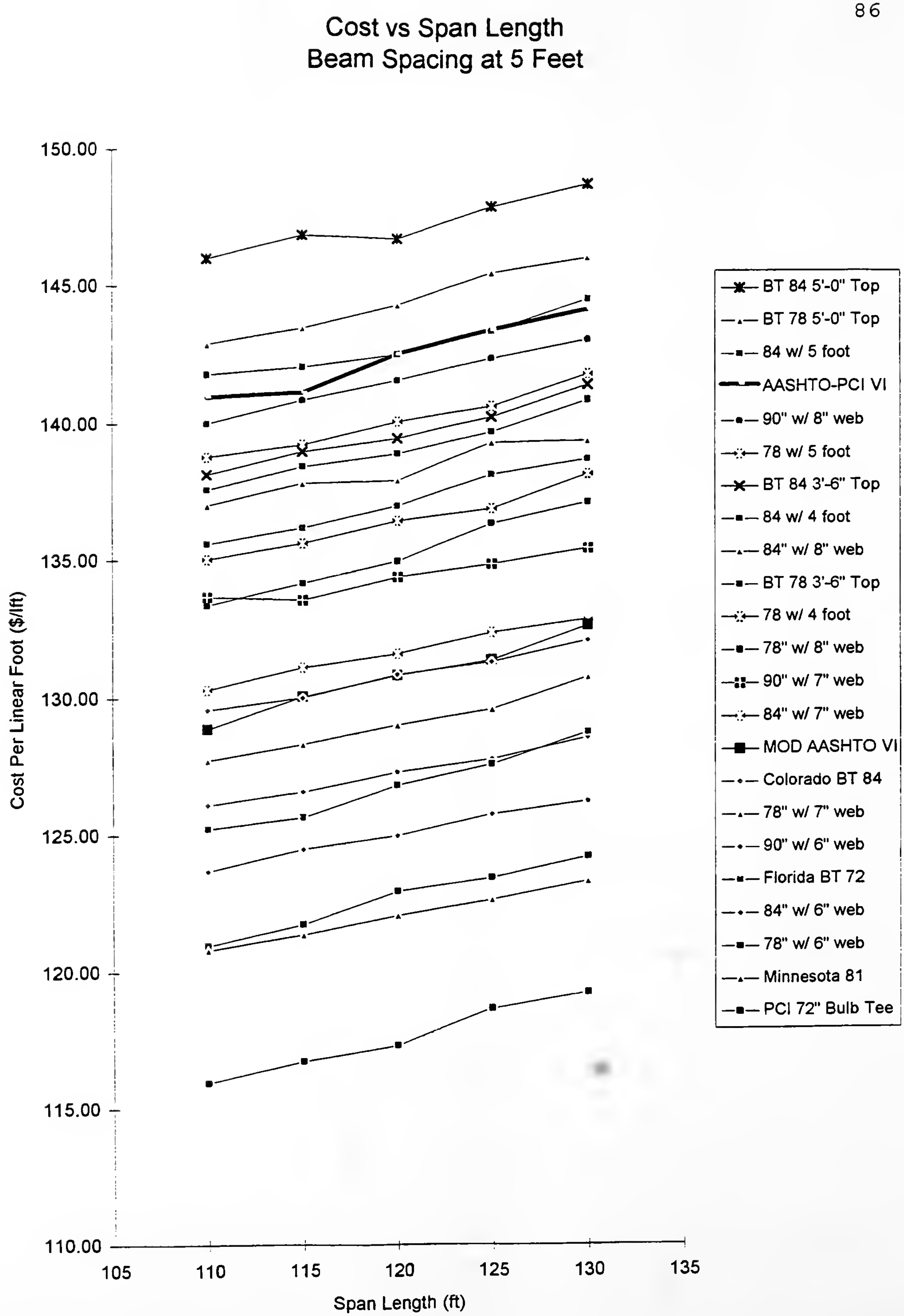

Cost vs Span Length
Beam Spacing at 5 Feet
100.00
95.00
90.00
85.00
80.00
75.00
70.00
Cost Per Linear Foot ($/lft)
25
30
35
40
45
50
55
Span Length (ft)
Penn 24/33
Penn 20/36
Ill. 42"
Penn 20/33
Penn 18/36
Missouri 3
W42G
AASHTO II
Penn 20/30
Texas B
Ill. 36"
Penn 18/33
Missouri 2
Penn 18/30
Minnesota 28M
AASHTO I

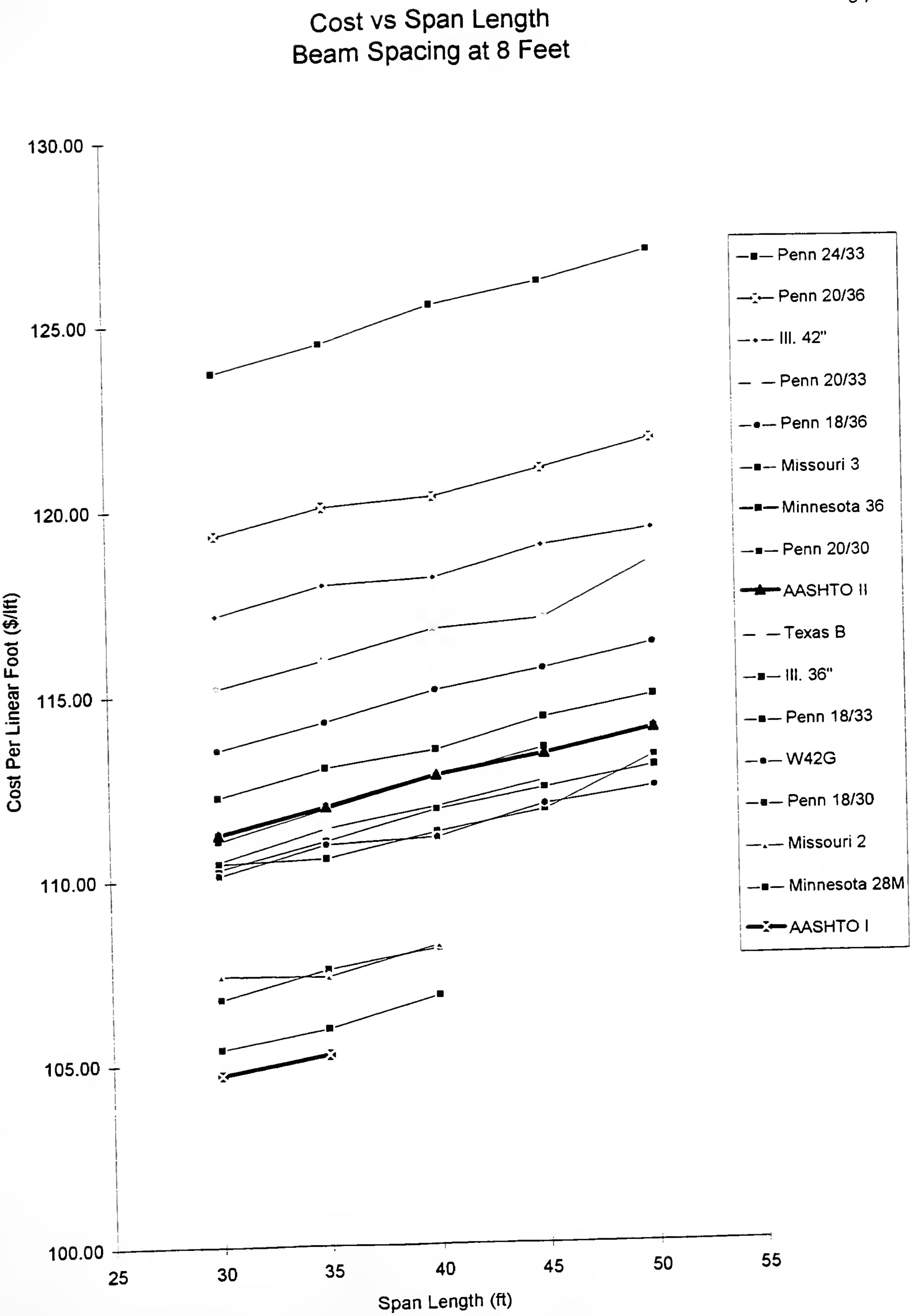
Cost vs Span Length
Beam Spacing at 5 Feet

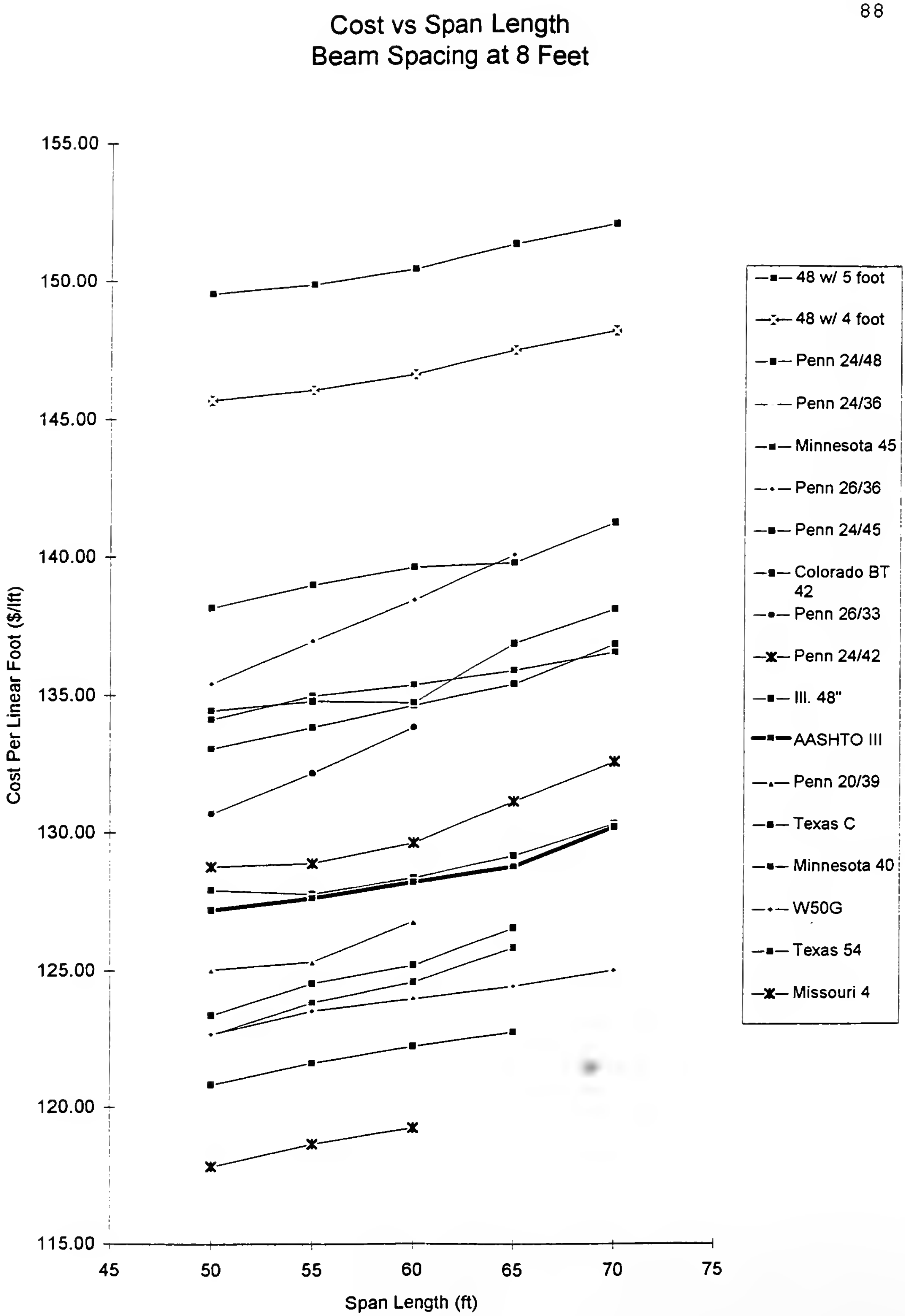



Cost vs Span Length
Beam Spacing at 5 Feet
130.00
125.00
120.00
115.00
110.00
105.00
100.00
95.00
Cost Per Linear Foot ($/lft)
65
70
75
80
85
90
95
Span Length (ft)
54 w/ 5 foot
BT 54 4'-0" Top
60 w/ 4 foot
BT 54 3'-6" Top
54 w/ 4 foot
Penn 24/60
Penn 24/54
AASHTO IV
60" w/ 7" web
Penn 24/51
Florida BT 54
Mod. IV 4' top
60" w/ 6" web
Minnesota 63
Mod. IV 2'-2" top
PCI 63" Bulb Tee
Minnesota 54M
MOD AASHTO IV
PCI 54" Bulb Tee
Missouri 6
Colorado G 68
Colorado G 54
Ill. 54"
W58G

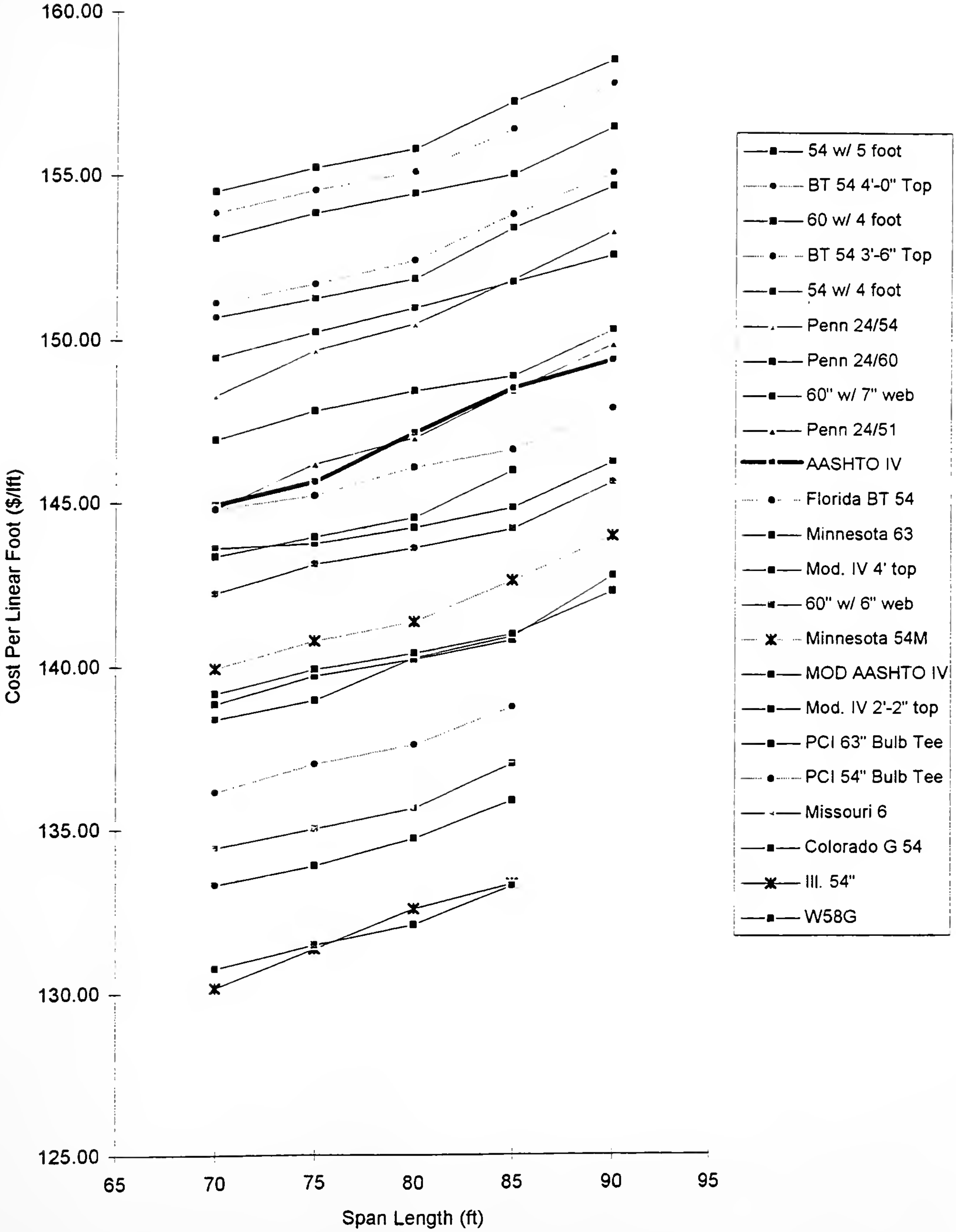

Cost vs Span Length
Beam Spacing at 5 Feet
Cost Per Linear Foot ($/lft)
145.00
140.00
135.00
130.00
125.00
120.00
115.00
110.00
85
90
95
100
105
110
115
Span Length (ft)
Penn 26/63
BT 72 5'-0" Top
BT 72 4'-6" Top
AASHTO-PCI V
72 w/ 5 foot
Penn 26/60
BT 63 4'-6" Top
66 w/ 5 foot
72 w/ 4 foot
BT 63 4'-0" Top
60 w/ 5 foot
72" w/ 8" web
66 w/ 4 foot
AASHTO V
66" w/ 8" web
Penn 24/63
MOD AASHTO V
72" w/ 7" web
60" w/ 8" web
Texas 72
Colorado BT 72
66" w/ 7" web
Florida BT 63
72" w/ 6" web
Minnesota 72
66" w/ 6" web
Wisconsin 70"
W74G


Cost vs Span Length
Beam Spacing at 5 Feet
Cost Per Linear Foot ($/lft)
150.00
145.00
140.00
135.00
130.00
125.00
120.00
115.00
110.00
105
110
115
120
125
130
135
Span Length (ft)
BT 84 5'-0" Top
BT 78 5'-0" Top
84 w/ 5 foot
AASHTO-PCI VI
90" w/ 8" web
78 w/ 5 foot
BT 84 3'-6" Top
84 w/ 4 foot
84" w/ 8" web
BT 78 3'-6" Top
78 w/ 4 foot
78" w/ 8" web
90" w/ 7" web
84" w/ 7" web
MOD AASHTO VI
Colorado BT 84
78" w/ 7" web
90" w/ 6" web
Florida BT 72
84" w/ 6" web
78" w/ 6" web
Minnesota 81
PCI 72" Bulb Tee

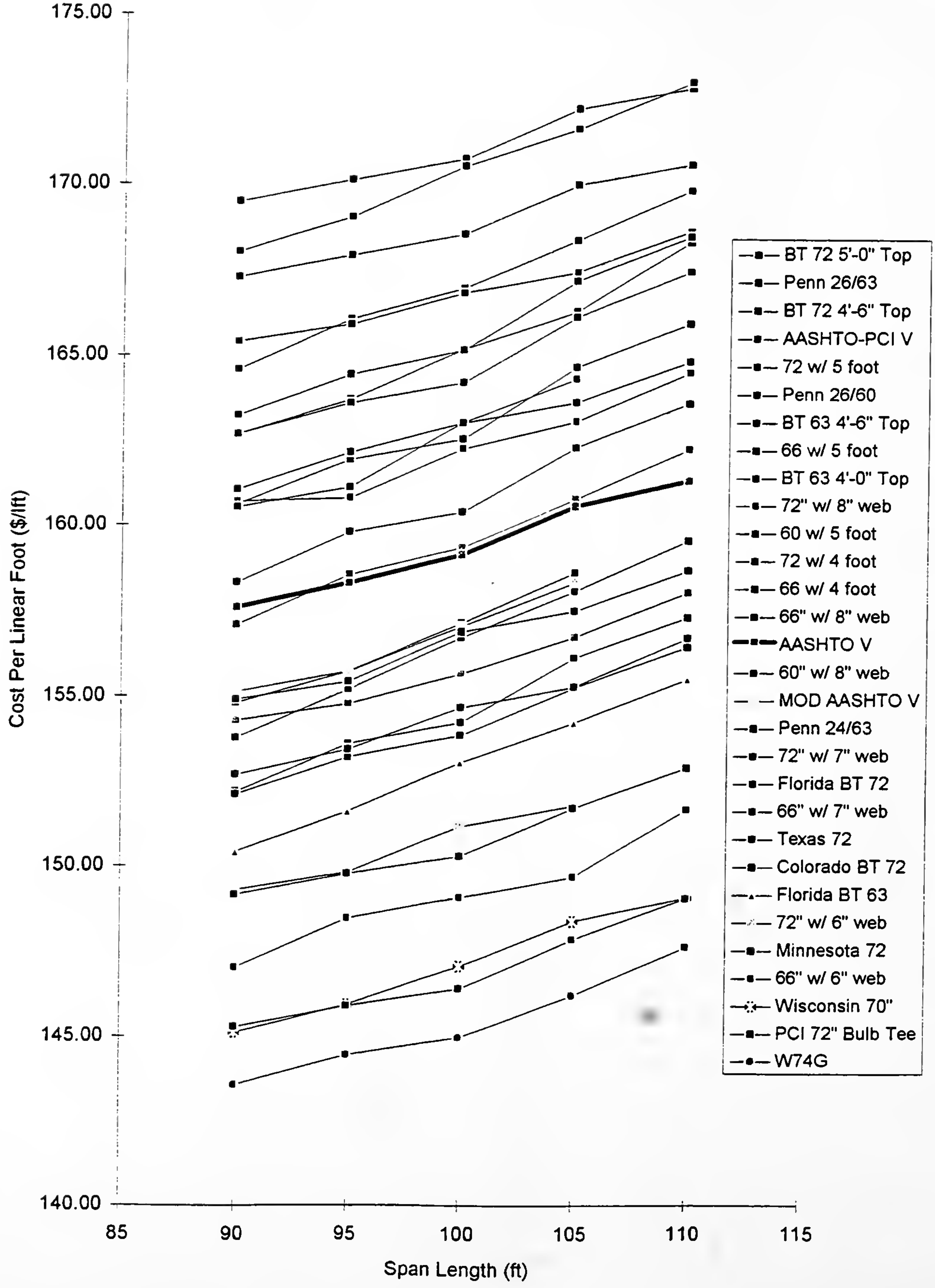

Cost vs Span Length
Beam Spacing at 8 Feet
Cost Per Linear Foot ($/lft)
130.00
125.00
120.00
115.00
110.00
105.00
100.00
25
30
35
40
45
50
55
Span Length (ft)
Penn 24/33
Penn 20/36
Ill. 42"
Penn 20/33
Penn 18/36
Missouri 3
Minnesota 36
Penn 20/30
AASHTO II
Texas B
Ill. 36"
Penn 18/33
W42G
Penn 18/30
Missouri 2
Minnesota 28M
AASHTO I

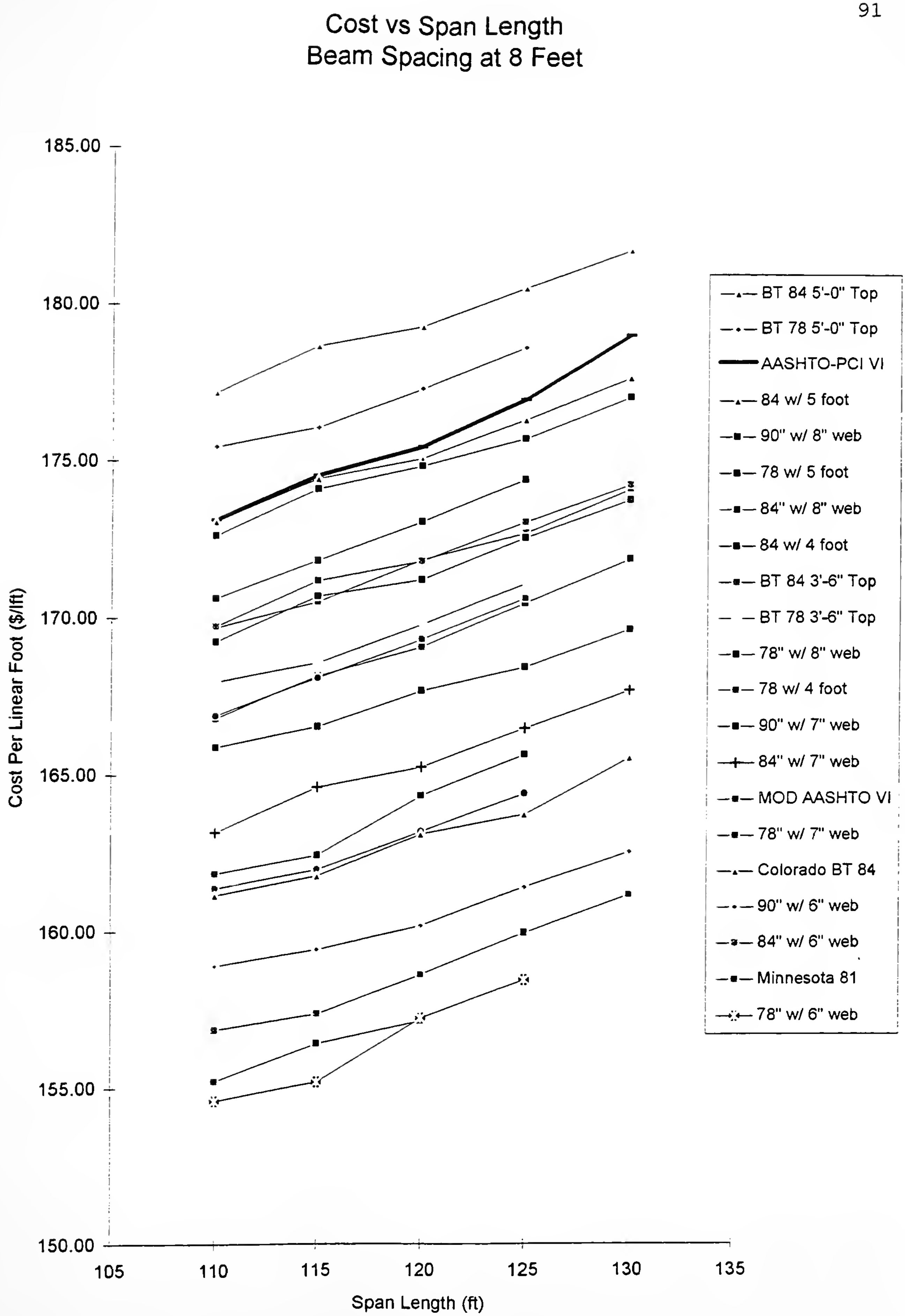

Cost vs Span Length
Beam Spacing at 8 Feet
155.00
150.00
145.00
140.00
135.00
130.00
125.00
120.00
115.00
Cost Per Linear Foot ($/lft)
45
50
55
60
65
70
75
Span Length (ft)
48 w/ 5 foot
48 w/ 4 foot
Penn 24/48
Penn 24/36
Minnesota 45
Penn 26/36
Penn 24/45
Colorado BT 42
Penn 26/33
Penn 24/42
Ill. 48"
AASHTO III
Penn 20/39
Texas C
Minnesota 40
W50G
Texas 54
Missouri 4

Cost vs Span Length
Beam Spacing at 8 Feet

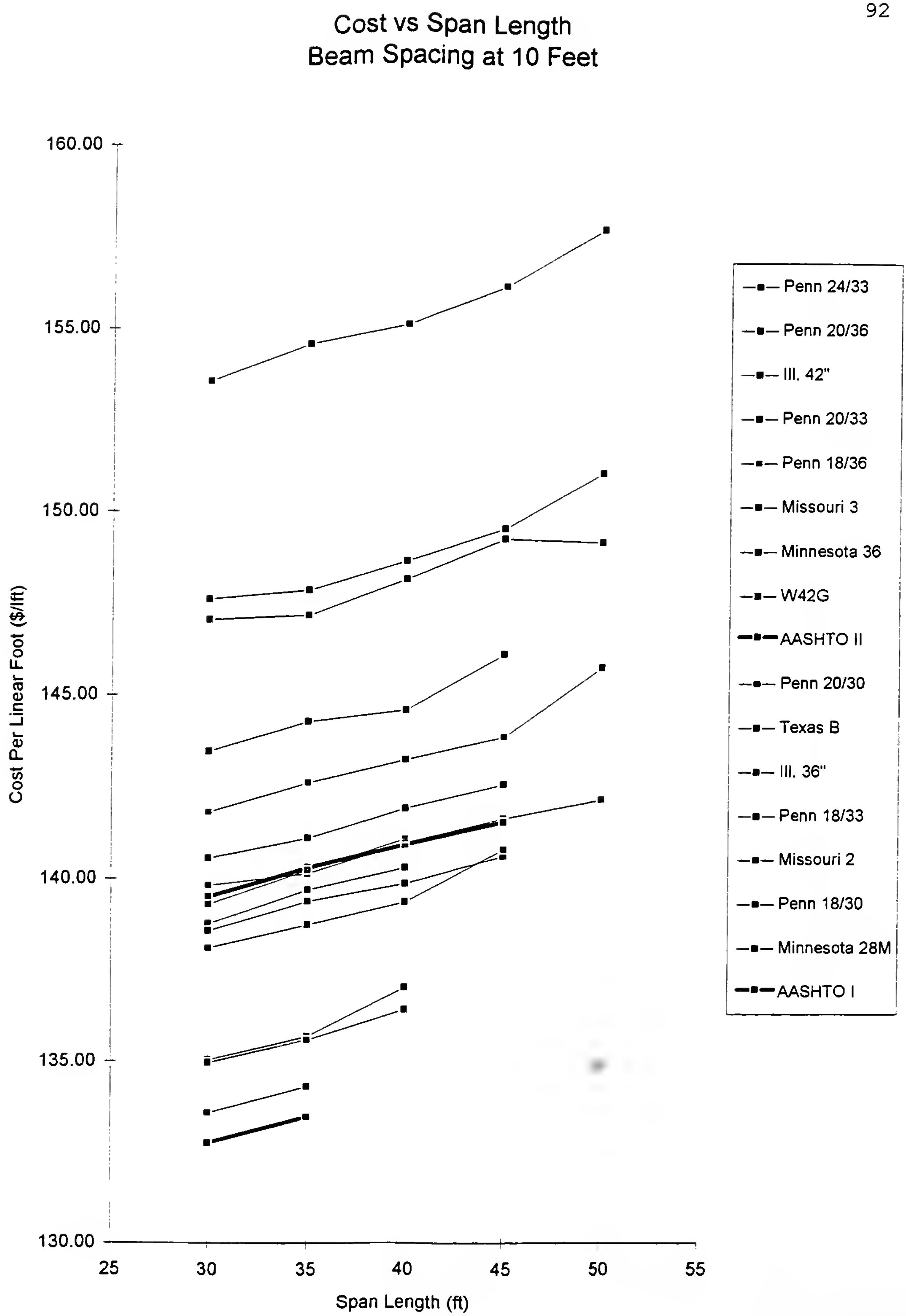


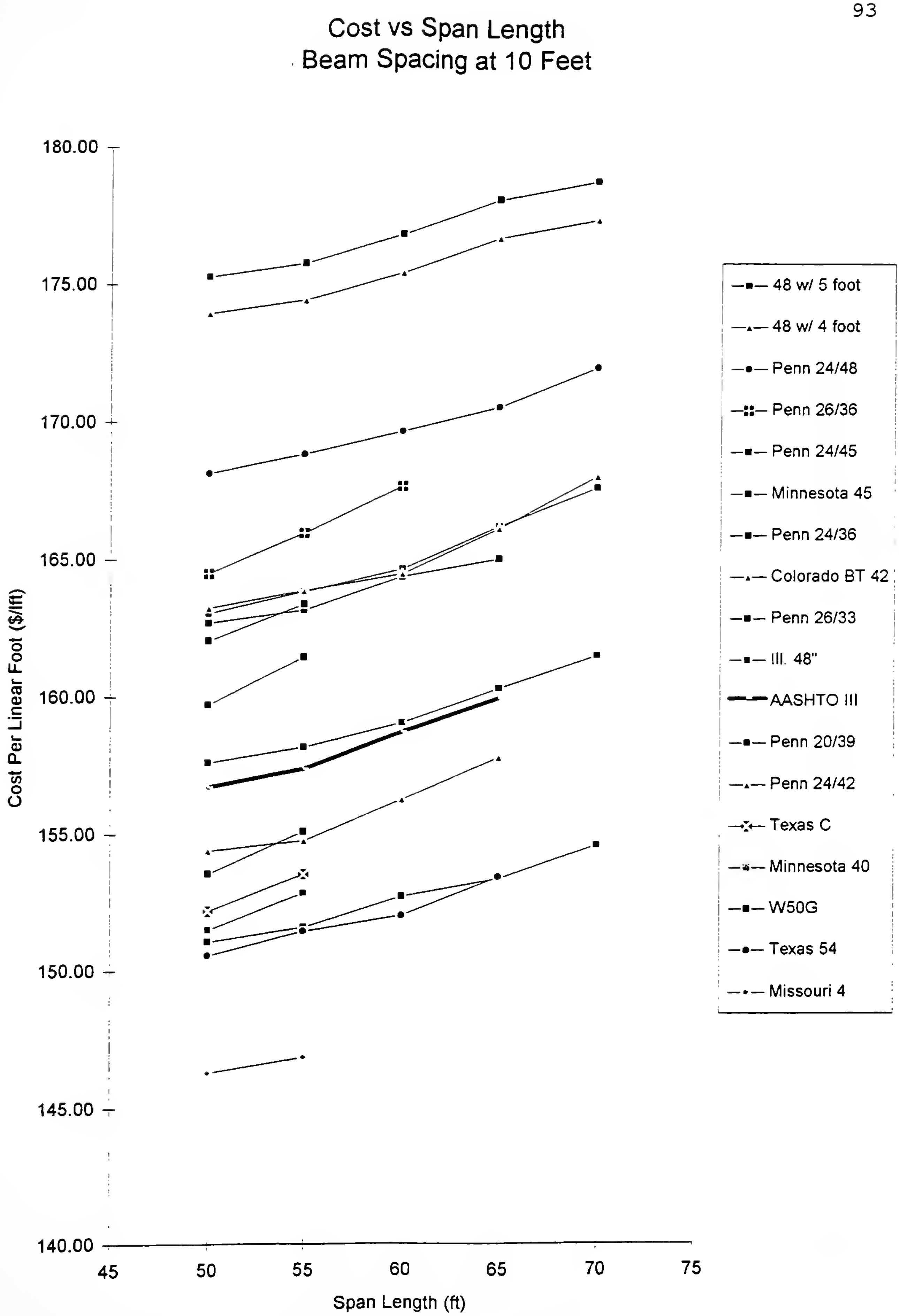
Cost vs Span Length
Beam Spacing at 8 Feet

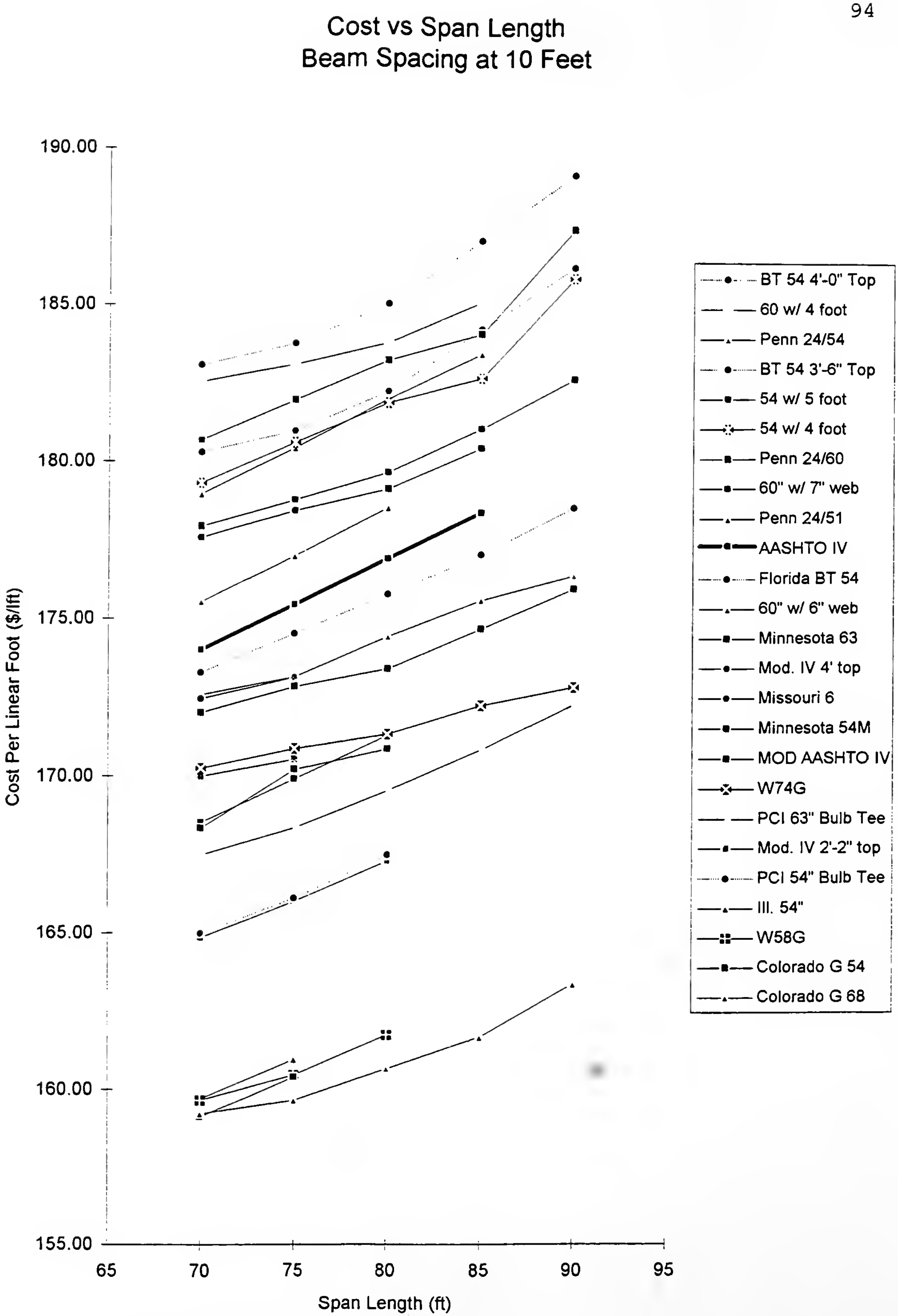


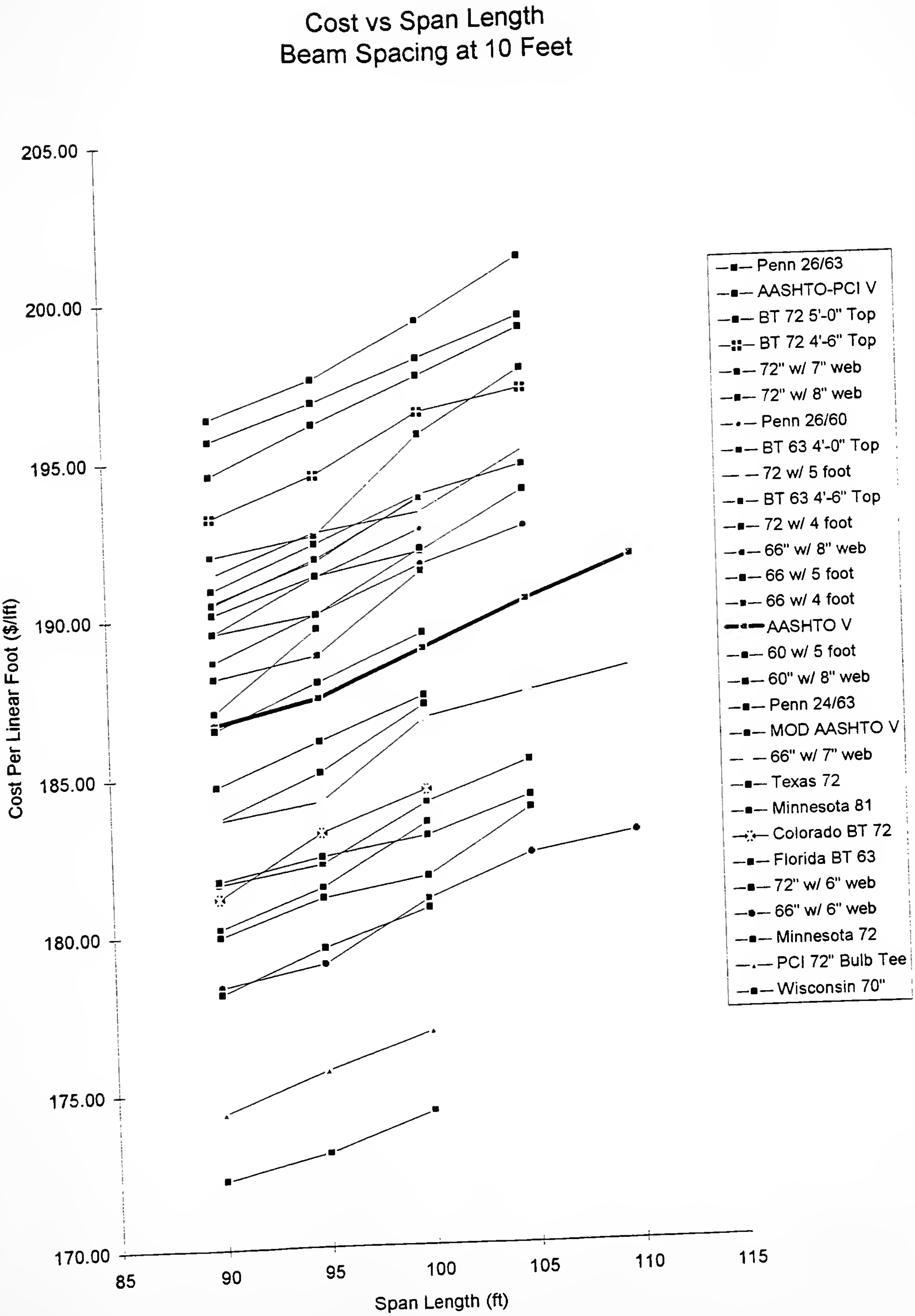


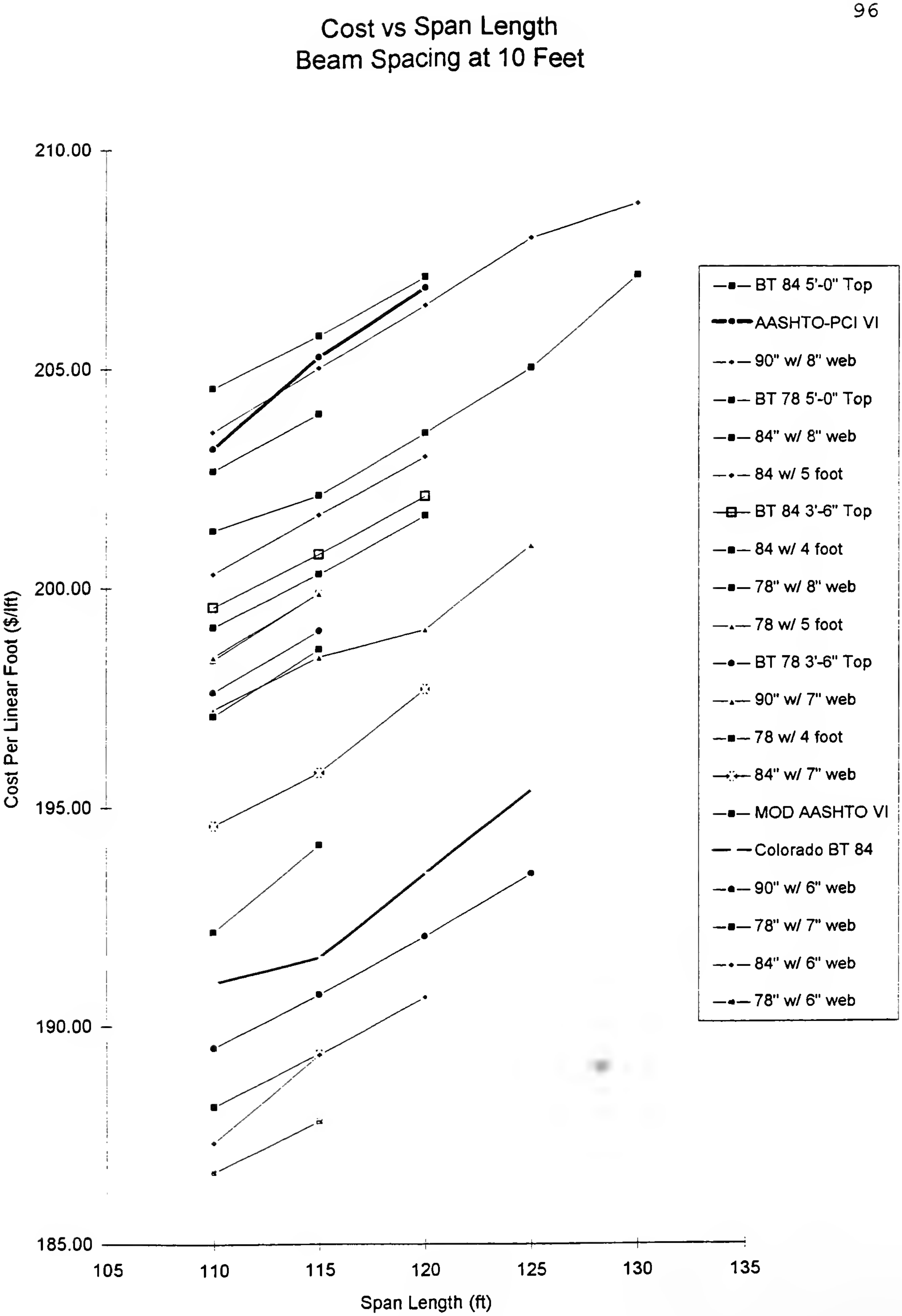
Cost vs Span Length
Beam Spacing at 8 Feet
Cost Per Linear Foot ($/lft)
185.00
180.00
175.00
170.00
165.00
160.00
155.00
150.00
105
110
115
120
125
130
135
Span Length (ft)
BT 84 5'-0" Top
BT 78 5'-0" Top
AASHTO-PCI VI
84 w/ 5 foot
90" w/ 8" web
78 w/ 5 foot
84" w/ 8" web
84 w/ 4 foot
BT 84 3'-6" Top
BT 78 3'-6" Top
78" w/ 8" web
78 w/ 4 foot
90" w/ 7" web
84" w/ 7" web
MOD AASHTO VI
78" w/ 7" web
Colorado BT 84
90" w/ 6" web
84" w/ 6" web
Minnesota 81
78" w/ 6" web


Cost vs Span Length
Beam Spacing at 10 Feet
160.00
155.00
150.00
145.00
140.00
135.00
130.00
Cost Per Linear Foot ($/lft)
25
30
35
40
45
50
55
Span Length (ft)
Penn 24/33
Penn 20/36
Ill. 42"
Penn 20/33
Penn 18/36
Missouri 3
Minnesota 36
W42G
AASHTO II
Penn 20/30
Texas B
Ill. 36"
Penn 18/33
Missouri 2
Penn 18/30
Minnesota 28M
AASHTO I


Cost vs Span Length
Beam Spacing at 10 Feet
Cost Per Linear Foot ($/lft)
180.00
175.00
170.00
165.00
160.00
155.00
150.00
145.00
140.00
45
50
55
60
65
70
75
Span Length (ft)
48 w/ 5 foot
48 w/ 4 foot
Penn 24/48
Penn 26/36
Penn 24/45
Minnesota 45
Penn 24/36
Colorado BT 42
Penn 26/33
Ill. 48"
AASHTO III
Penn 20/39
Penn 24/42
Texas C
Minnesota 40
W50G
Texas 54
Missouri 4


Cost vs Span Length
Beam Spacing at 10 Feet
190.00
185.00
180.00
175.00
170.00
165.00
160.00
155.00
Cost Per Linear Foot ($/lft)
65
70
75
80
85
90
95
Span Length (ft)
BT 54 4'-0" Top
60 w/ 4 foot
Penn 24/54
BT 54 3'-6" Top
54 w/ 5 foot
54 w/ 4 foot
Penn 24/60
60" w/ 7" web
Penn 24/51
AASHTO IV
Florida BT 54
60" w/ 6" web
Minnesota 63
Mod. IV 4' top
Missouri 6
Minnesota 54M
MOD AASHTO IV
W74G
PCI 63" Bulb Tee
Mod. IV 2'-2" top
PCI 54" Bulb Tee
Ill. 54"
W58G
Colorado G 54
Colorado G 68


Cost vs Span Length
Beam Spacing at 10 Feet
205.00
200.00
195.00
190.00
185.00
180.00
175.00
170.00
Cost Per Linear Foot ($/lft)
85
90
95
100
105
110
115
Span Length (ft)
Penn 26/63
AASHTO-PCI V
BT 72 5'-0" Top
BT 72 4'-6" Top
72" w/ 7" web
72" w/ 8" web
Penn 26/60
BT 63 4'-0" Top
72 w/ 5 foot
BT 63 4'-6" Top
72 w/ 4 foot
66" w/ 8" web
66 w/ 5 foot
66 w/ 4 foot
AASHTO V
60 w/ 5 foot
60" w/ 8" web
Penn 24/63
MOD AASHTO V
66" w/ 7" web
Texas 72
Minnesota 81
Colorado BT 72
Florida BT 63
72" w/ 6" web
66" w/ 6" web
Minnesota 72
PCI 72" Bulb Tee
Wisconsin 70"


Cost vs Span Length
Beam Spacing at 10 Feet
Cost Per Linear Foot ($/lft)
210.00
205.00
200.00
195.00
190.00
185.00
105
110
115
120
125
130
135
Span Length (ft)
BT 84 5'-0" Top
AASHTO-PCI VI
90" w/ 8" web
BT 78 5'-0" Top
84" w/ 8" web
84 w/ 5 foot
BT 84 3'-6" Top
84 w/ 4 foot
78" w/ 8" web
78 w/ 5 foot
BT 78 3'-6" Top
90" w/ 7" web
78 w/ 4 foot
84" w/ 7" web
MOD AASHTO VI
Colorado BT 84
90" w/ 6" web
78" w/ 7" web
84" w/ 6" web
78" w/ 6" web

Appendix F

PROPERTIES OF THE FINAL GIRDERS

SPAN RANGE 30-50 FEET

GIRDER	RANK	HEIGHT (in.)	TOP FLANGE (in.)	BOT FLANGE (in.)	WEB (in.)	AREA (in.^2)	AVG. STRANDS	AVG. STIRRUPS
AASHTO I	**1/18**	28.0	12.0	16.0	6.0	276.0	10	32
Minn. 28M	2/18	28.0	12.0	18.0	6.0	285.0	10	32
Missouri 2	3/18	32.0	13.0	17.0	6.0	311.5	8	28
Penn. 18/30	4/18	30.0	12.0	18.0	6.0	303.0	10	34
AASHTO II	**10/18**	36.0	12.0	18.0	6.0	369.0	8	28

SPAN RANGE 50-70 FEET

GIRDER	RANK	HEIGHT (in.)	TOP FLANGE (in.)	BOT FLANGE (in.)	WEB (in.)	AREA (in.^2)	AVG. STRANDS	AVG. STIRRUPS
Missouri 4	1/18	45.0	13.0	17.0	6.0	429.5	16	46
Wash. 50G	2/18	50.0	20.0	25.0	6.0	526.5	14	48
Minn. 40	3/18	40.0	16.0	22.0	6.0	485.0	18	56
Texas C	4/18	40.0	14.0	22.0	7.0	495.5	18	54
AASHTO III	**7/18**	45.0	16.0	22.0	7.0	560.0	16	50

PROPERTIES OF THE FINAL GIRDERS

SPAN RANGE 70-90 FEET

GIRDER	RANK	HEIGHT (in.)	TOP FLANGE (in.)	BOT FLANGE (in.)	WEB (in.)	AREA (in.^2)	AVG. STRANDS	AVG. STIRRUPS
Wash. 58G	1/24	58.0	25.0	25.0	6.0	604.5	20	60
Illinois 54"	**2/24**	54.0	20.0	22.0	6.0	599.0	24	62
Colo. G54	3/24	54.0	28.0	24.0	6.0	627.1	22	66
Missouri 6	4/24	54.0	24.0	24.0	6.5	644.1	22	62
PCI 54" BT	5/24	54.0	42.0	26.0	6.0	655.5	22	66
AASHTO IV	**16/24**	54.0	20.0	26.0	8.0	789.0	24	60
Indiana BT 54	22/24	54.0	42.0	25.0	7.0	848.0	22	66

Denotes requirement of end blocks.

SPAN RANGE 90-110 FEET

GIRDER	RANK	HEIGHT (in.)	TOP FLANGE (in.)	BOT FLANGE (in.)	WEB (in.)	AREA (in.^2)	AVG. STRANDS	AVG. STIRRUPS
Wash. 74G	1/30	73.5	43.0	25.0	6.0	745.4	24	66
PCI 72" BT	2/30	72.0	42.0	26.0	6.0	763.5	24	68
Wisconsin 70	3/30	70.0	30.0	26.0	6.0	770.0	26	70
Colo. BT 72	4/30	72.0	43.0	27.0	7.0	860.5	26	70
Texas 72	5/30	72.0	22.0	22.0	7.0	864.0	26	66
Ky. 66 w/ 7"	6/30	66.0	35.0	25.0	7.0	834.0	28	74
*** AASHTO V**	**16/30**	72.0	20.0	26.0	8.0	933.0	26	66
Indiana BT 63	22/30	63.0	48.0	25.0	7.0	942.8	30	78

* INDOT version of AASHTO Type V girder

PROPERTIES OF THE FINAL GIRDERS

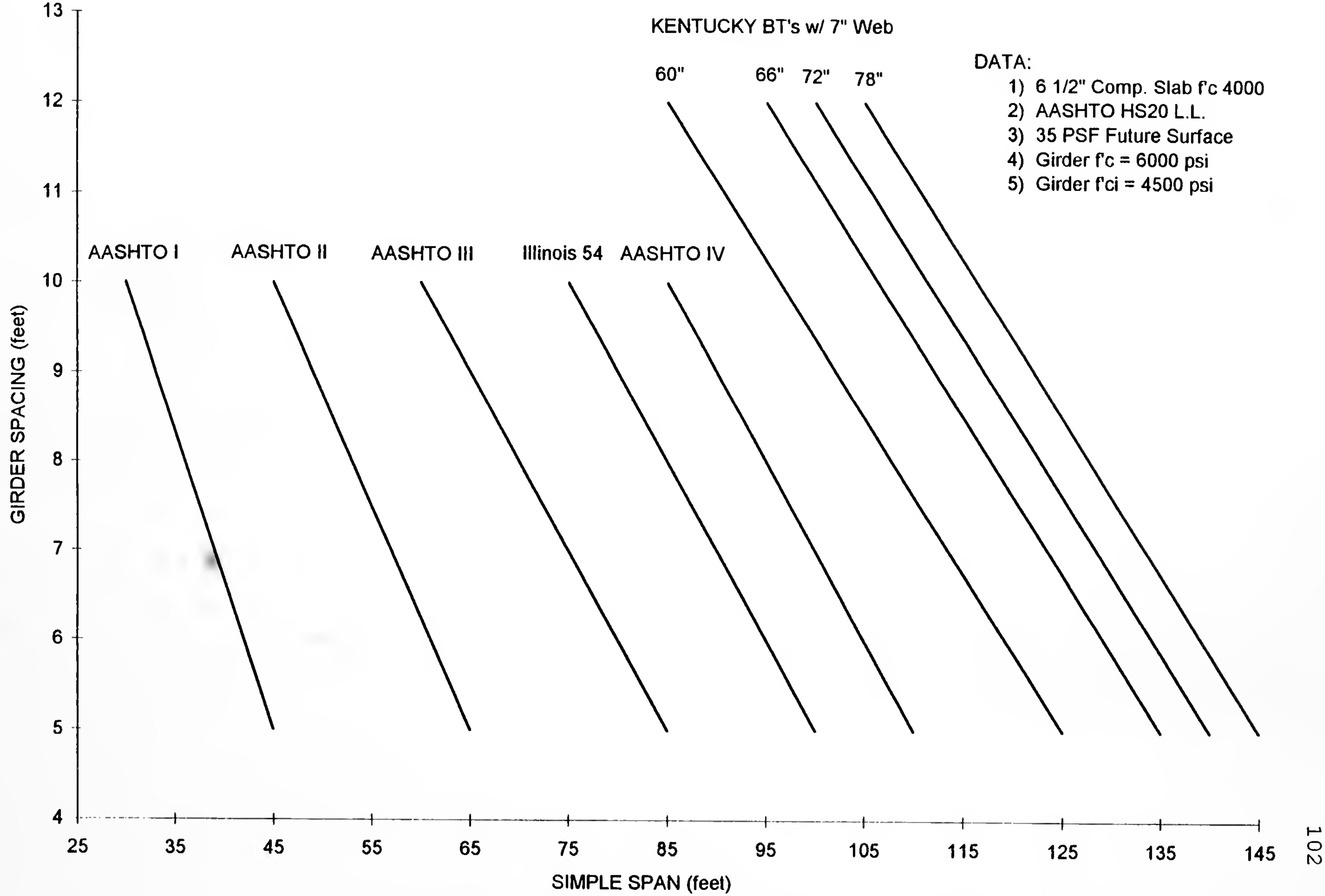
SPAN RANGE 110-130 FEET

GIRDER	RANK	HEIGHT (in.)	TOP FLANGE (in.)	BOT FLANGE (in.)	WEB (in.)	AREA (in.^2)	AVG. STRANDS	AVG. STIRRUPS
Ky. 78 w/ 6"	1/21	78.0	34.0	24.0	6.0	840.0	36	84
Minn. 81	2/21	81.0	30.0	26.0	6.0	836.6	32	82
Ky. 84 w/ 6"	3/21	84.0	34.0	24.0	6.0	876.0	32	76
Colo. BT 84	4/21	84.0	43.0	27.0	7.0	944.5	32	80
Ky. 78 w/ 7"	5/21	78.0	35.0	25.0	7.0	918.0	36	82
Indiana BT 78	12/21	78.0	42.0	25.0	7.0	1016.0	36	84
AASHTO VI	**19/21**	72.0	42.0	28.0	8.0	1072.6	40	90

Denotes requirement of end blocks.

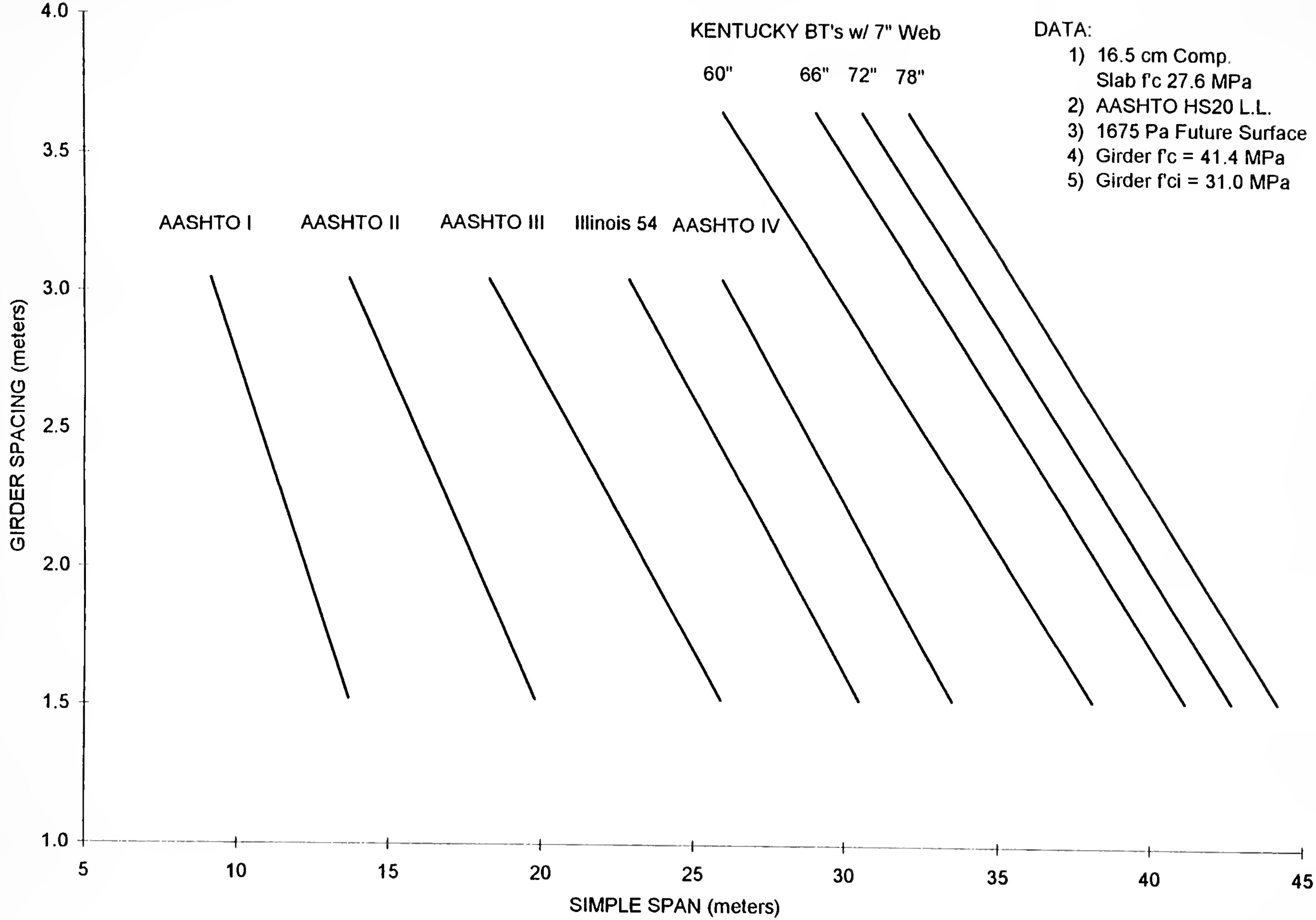
Appendix G

PRESTRESSED CONCRETE I-BEAM SELECTION CHART



Beam spans may increase 5 to 10 feet when using 7000 psi concrete or continuous spans.

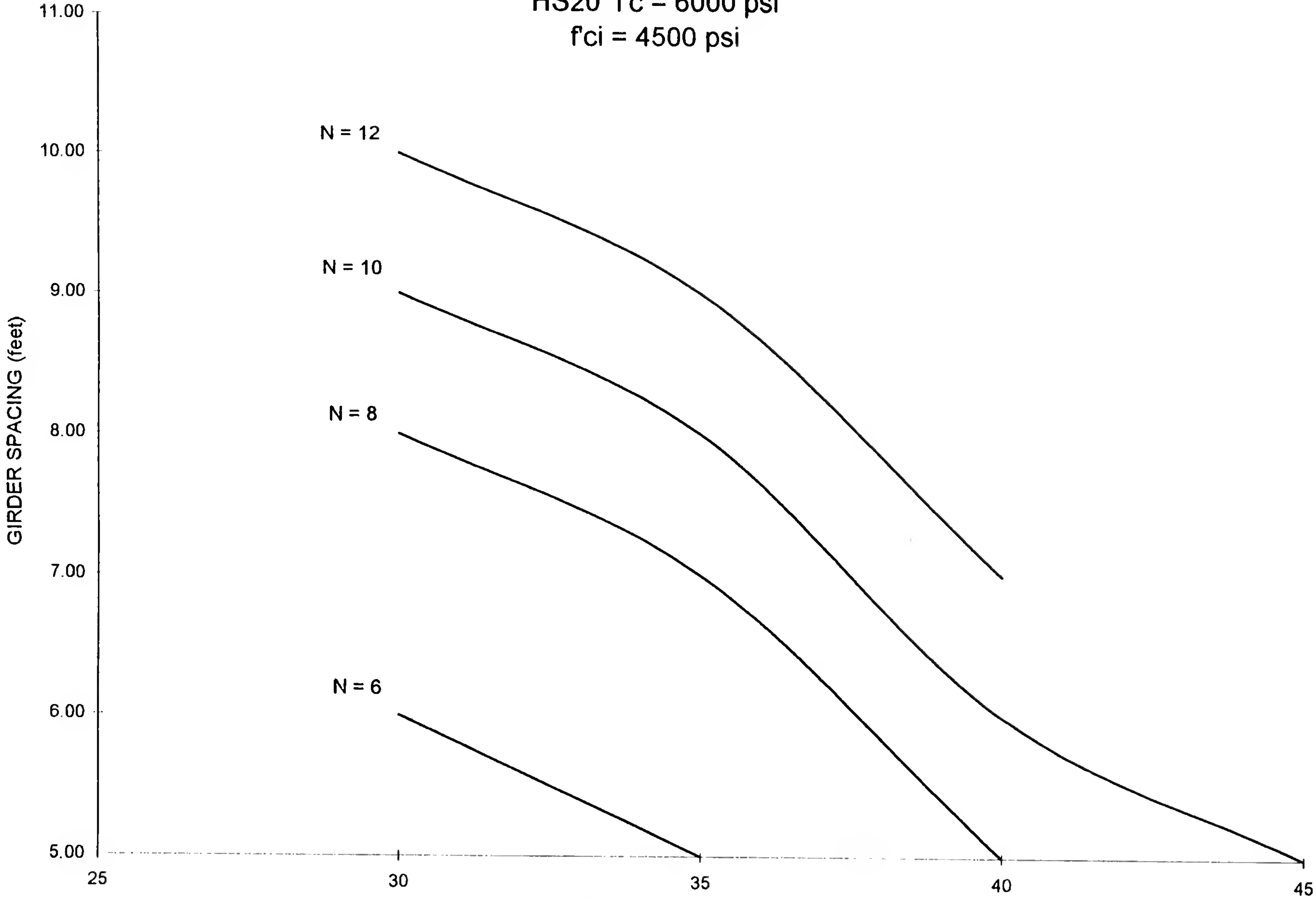
PRESTRESSED CONCRETE I-BEAM SELECTION CHART (METRIC)



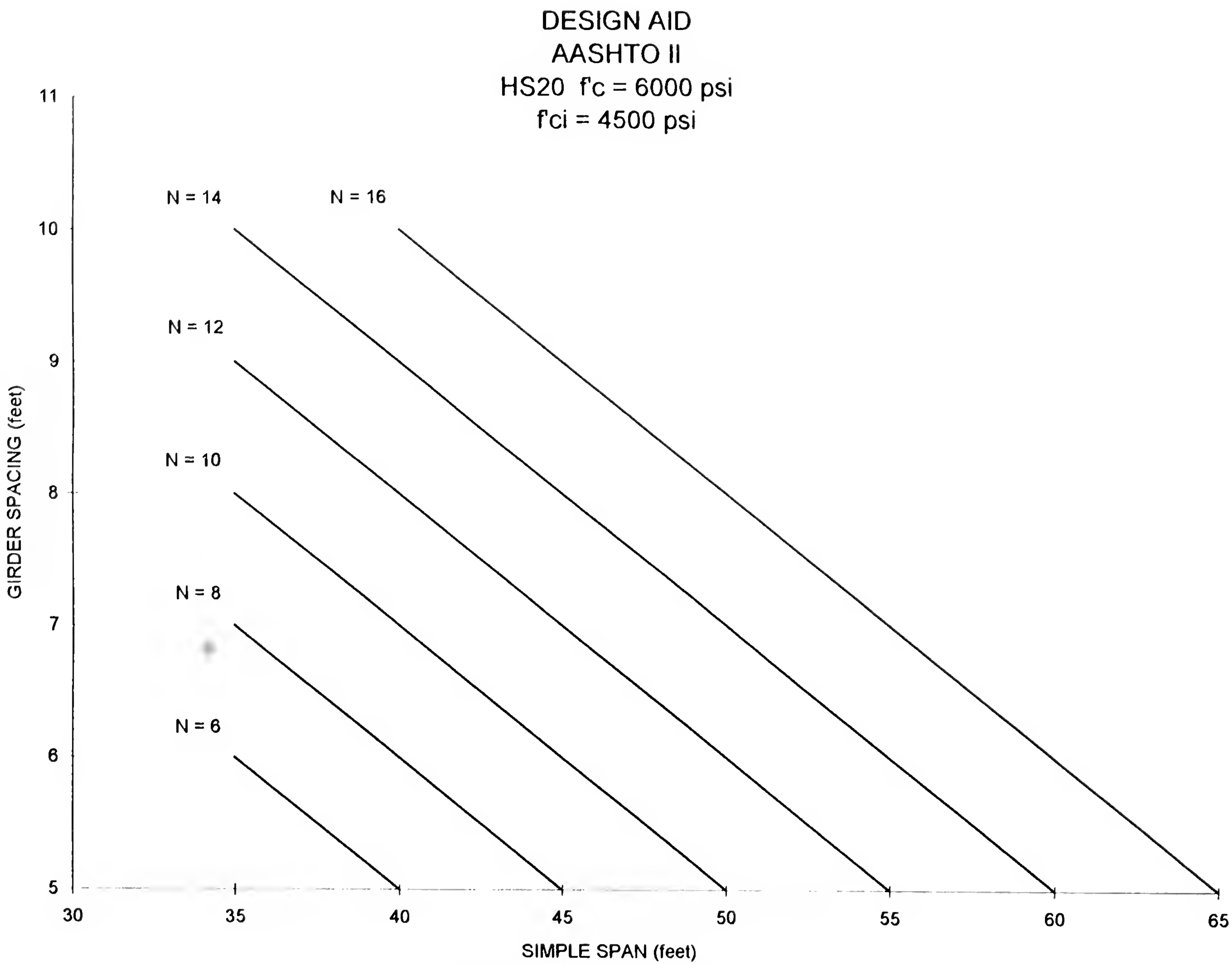
Beam spans may increase 1.5 to 3 meters when using 48.3 MPa concrete or continuous spans.

Appendix H

DESIGN AID
AASHTO I
HS20 f'c = 6000 psi
f'ci = 4500 psi

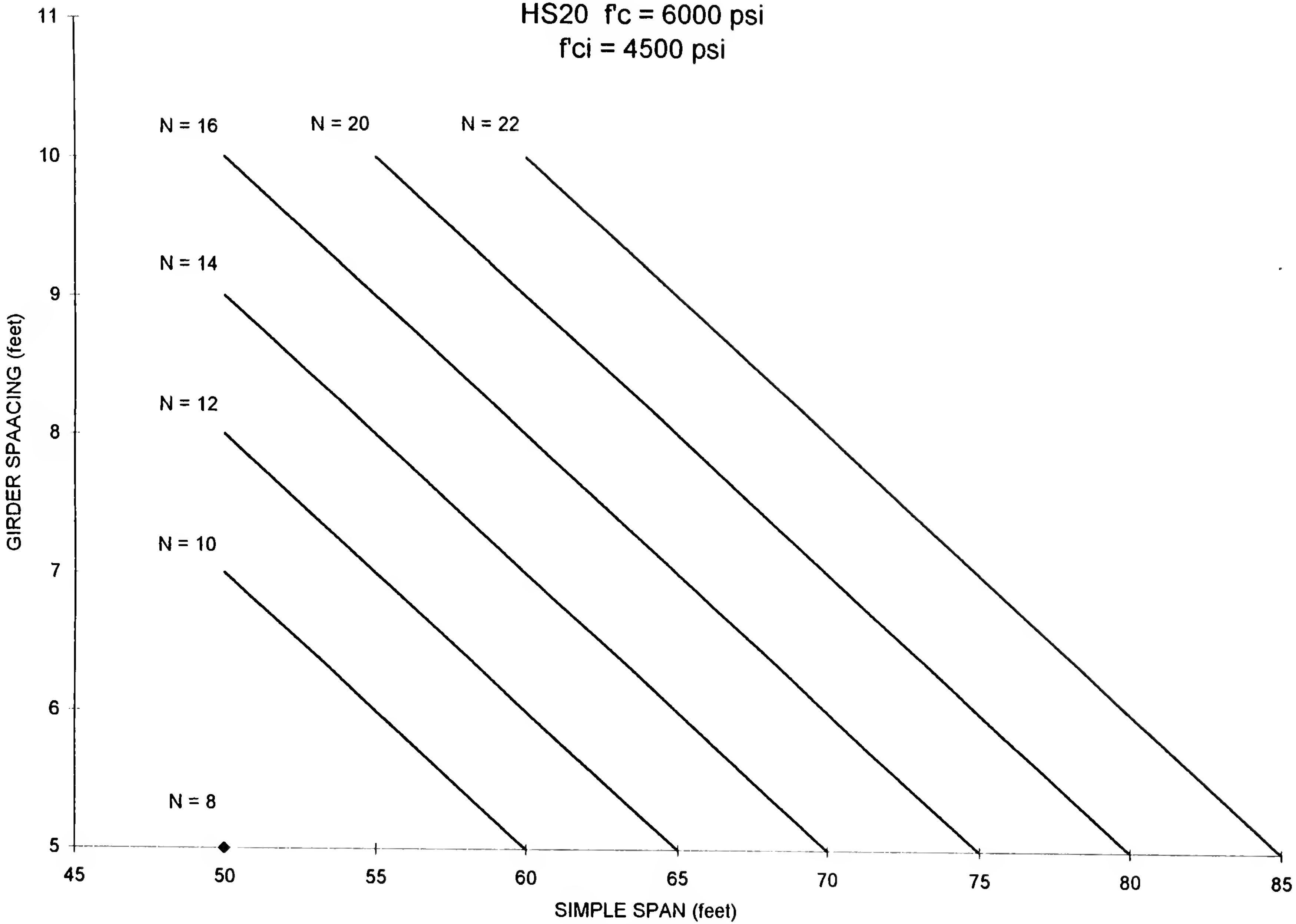


N = Number of bottom prestressing strands.



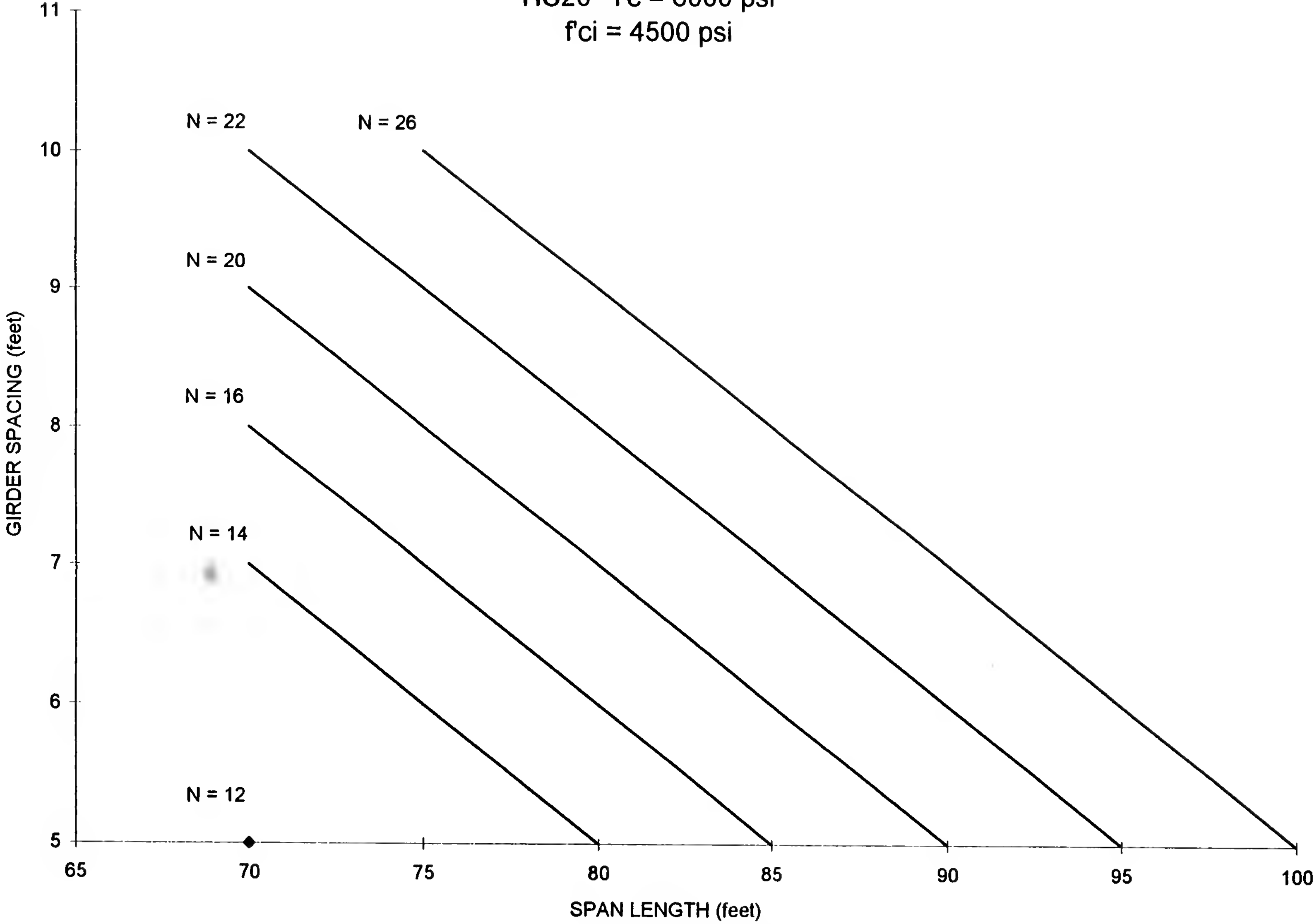
N = Number of bottom prestressing strands.

DESIGN AID
AASHTO III
HS20 f'c = 6000 psi
f'ci = 4500 psi



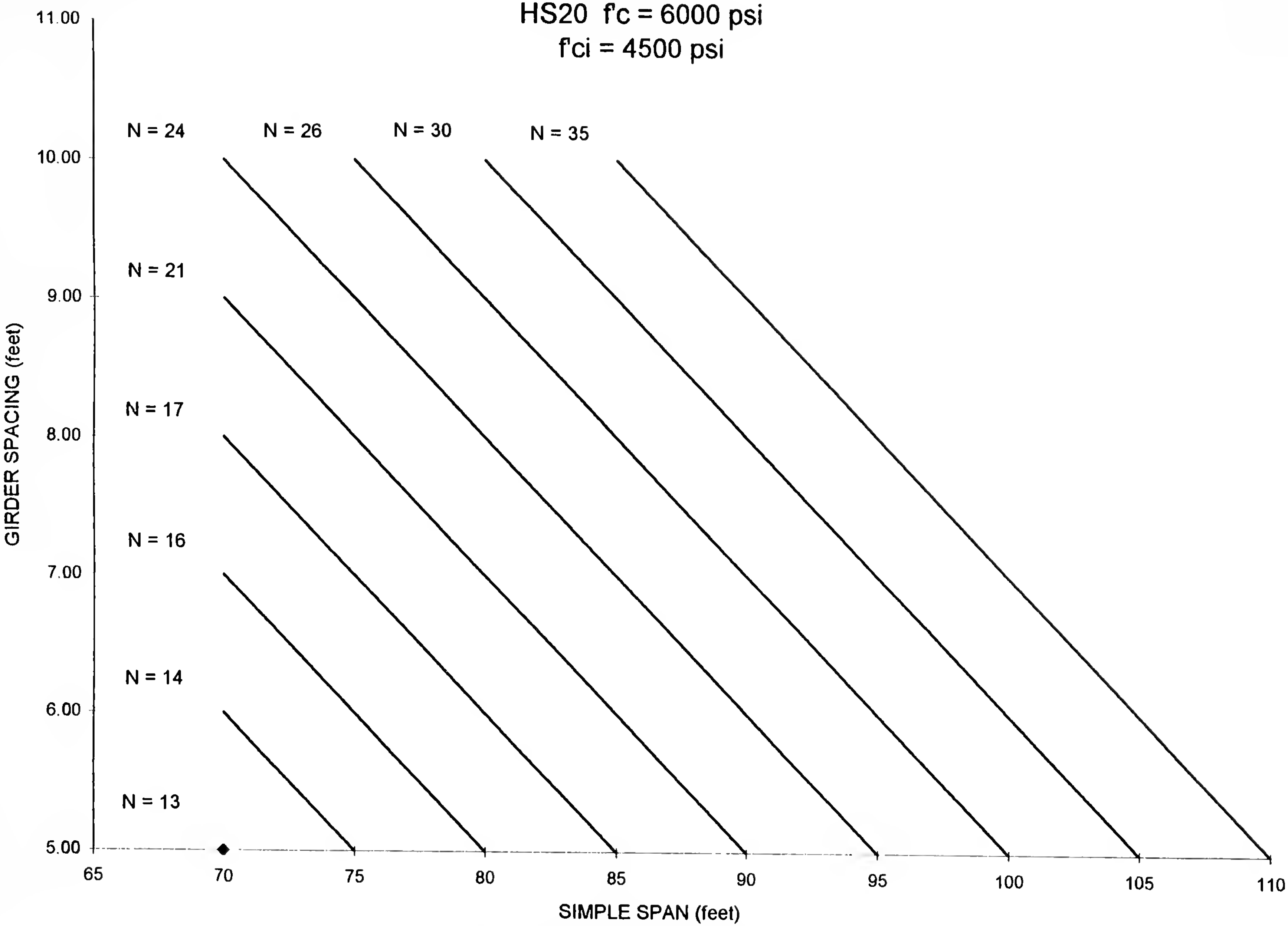
N = Number of bottom prestressing strands.

DESIGN AID
Illinois 54"
HS20 f'c = 6000 psi
f'ci = 4500 psi

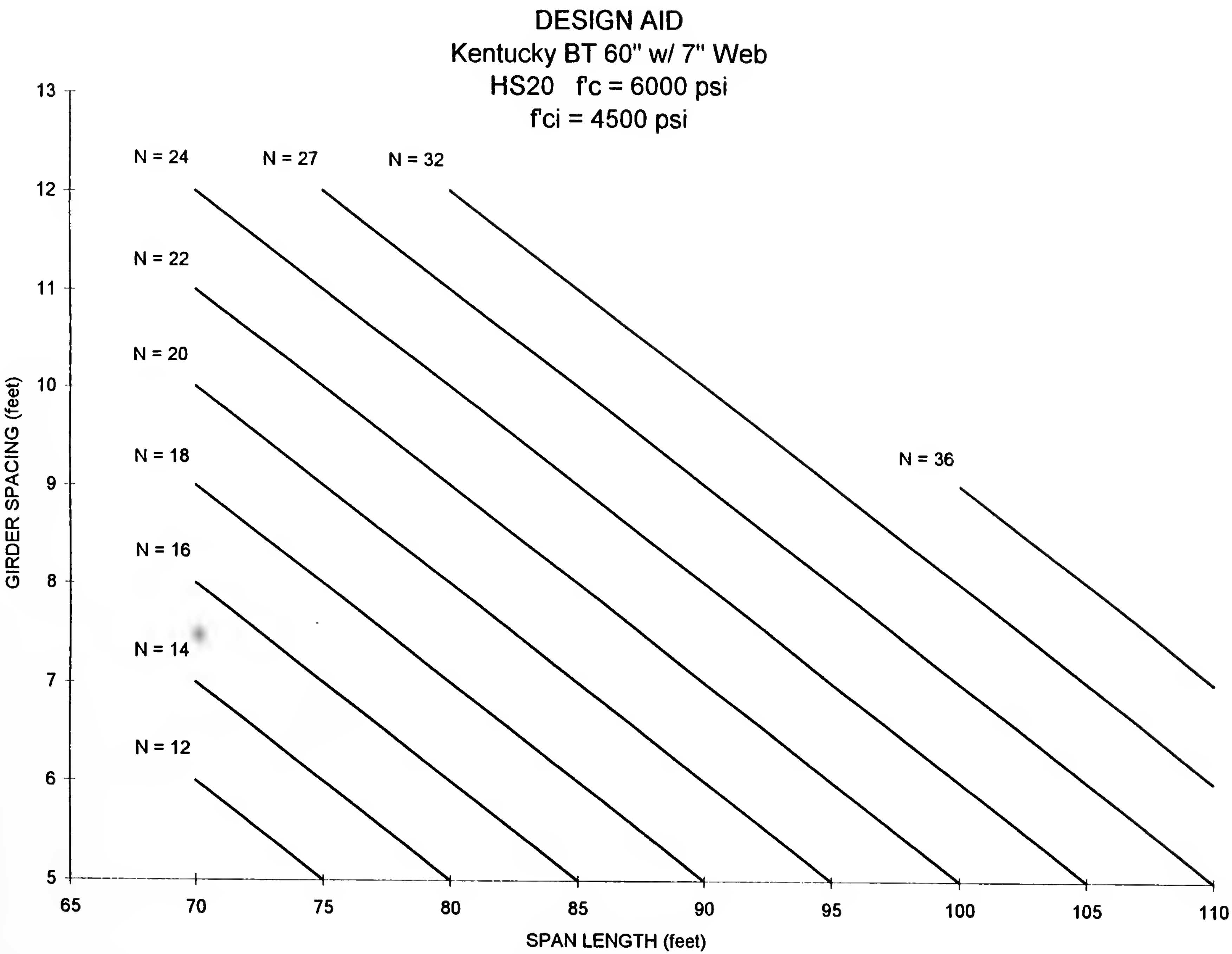


N = Number of bottom prestressing strands.

DESIGN AID
AASHTO IV
HS20 f'c = 6000 psi
f'ci = 4500 psi

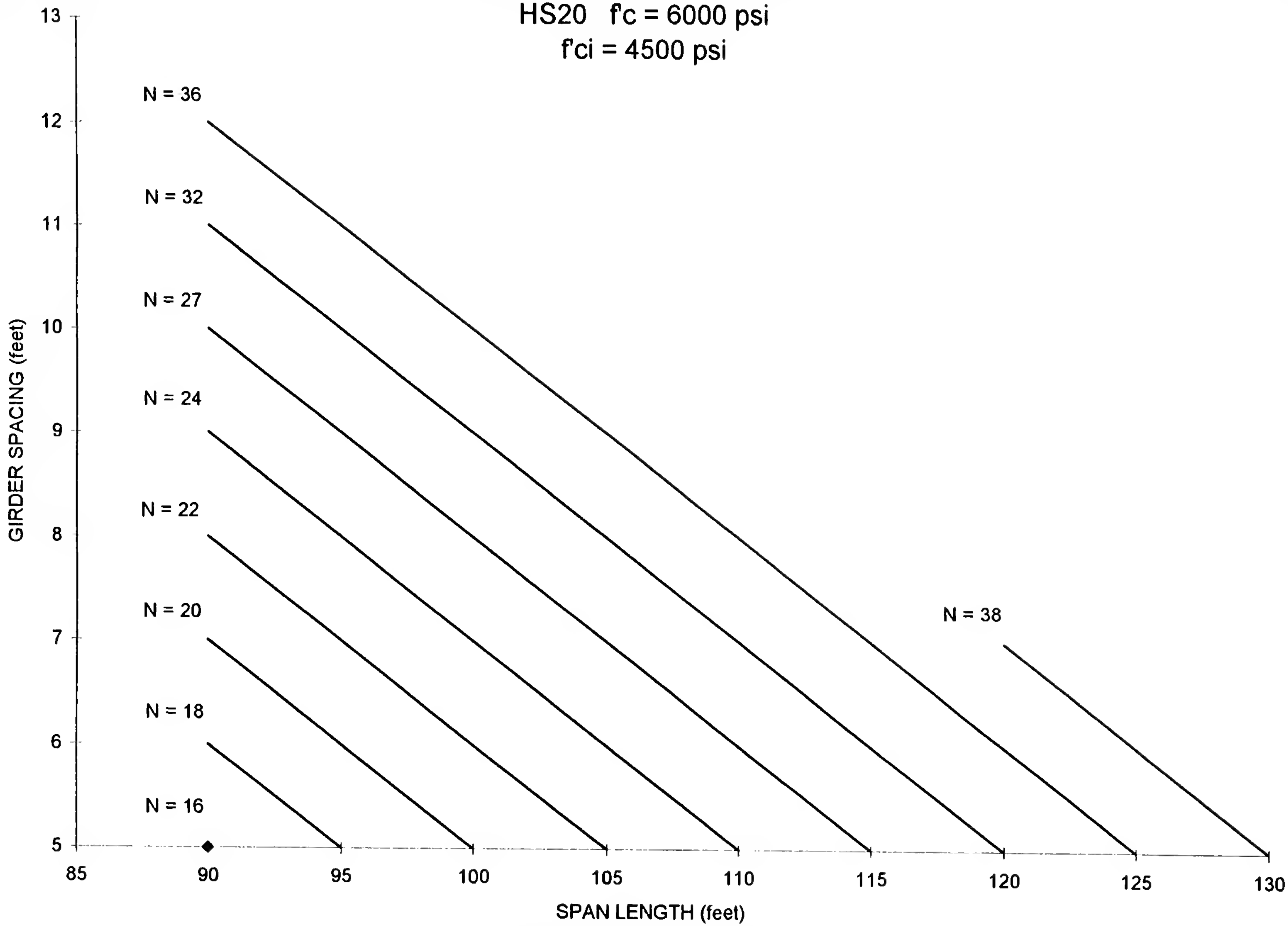


N = Number of bottom prestressing strands.



N = Number of prestressing strands.

DESIGN AID
Kentucky BT 66" w/ 7" Web
HS20   f'c = 6000 psi
f'ci = 4500 psi



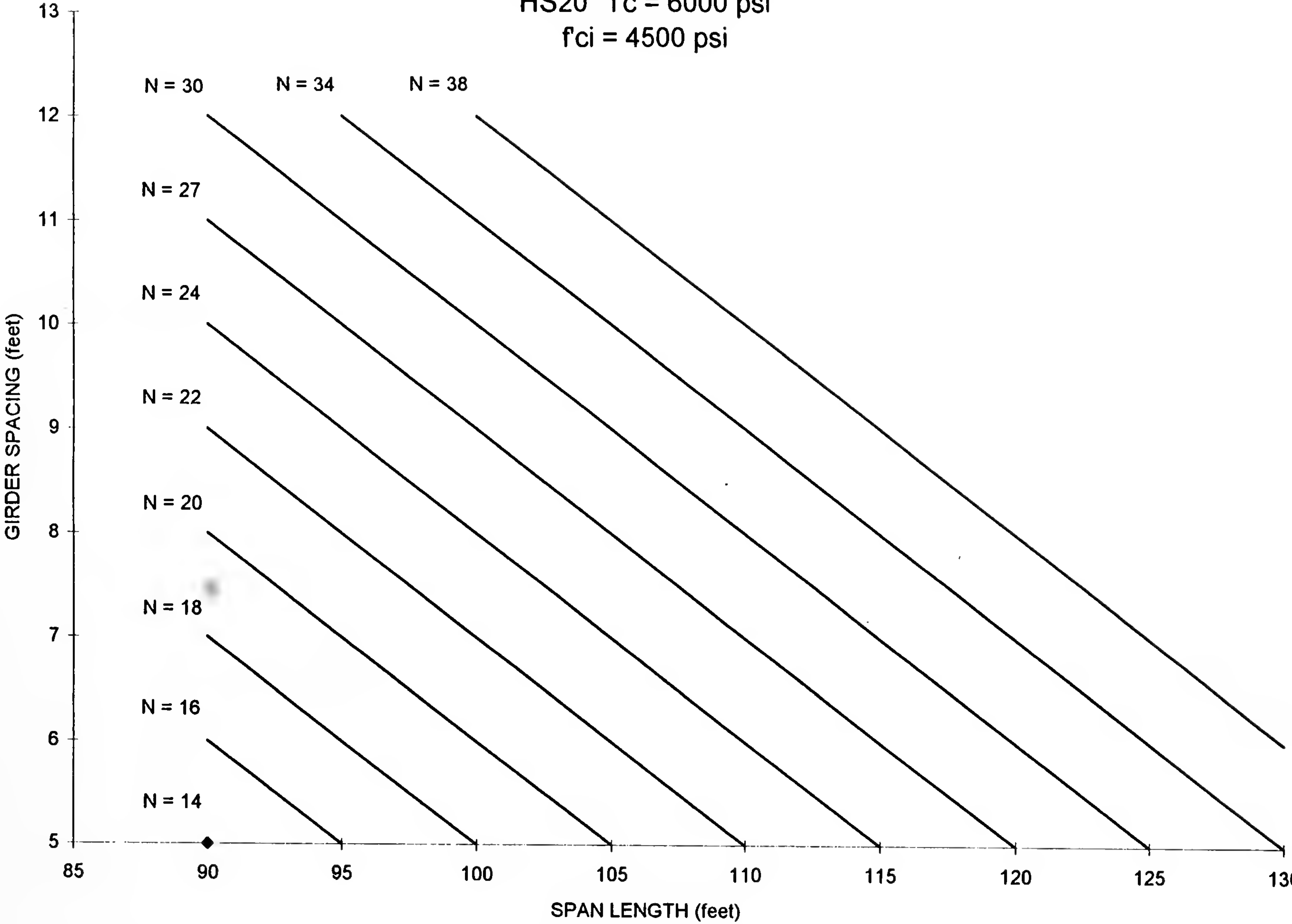
N = Number of prestressing strands.

DESIGN AID

Kentucky 72" w/ 7" Web

HS20 f'c = 6000 psi

f'ci = 4500 psi



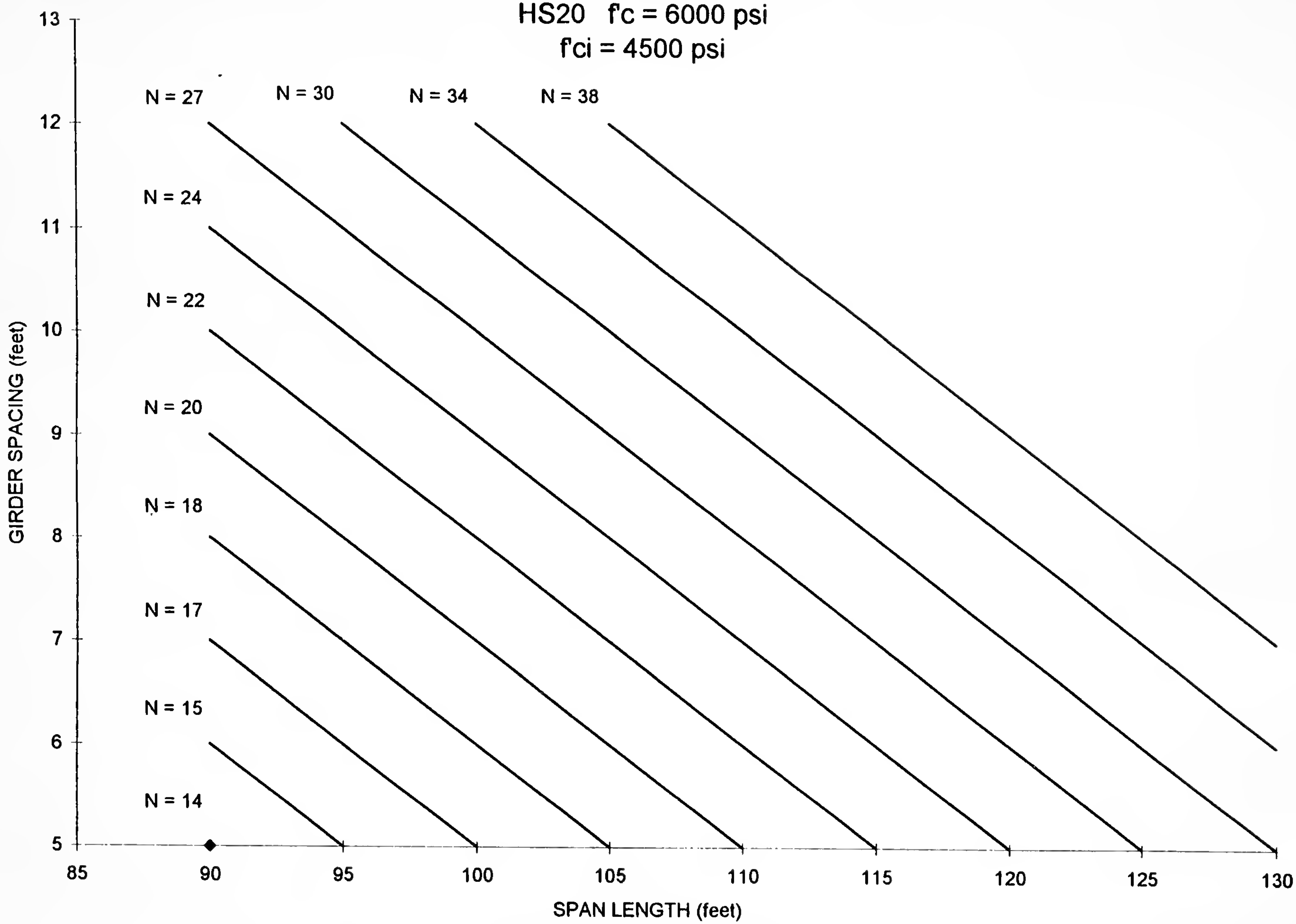
N = Number of prestressing strands.

DESIGN AID

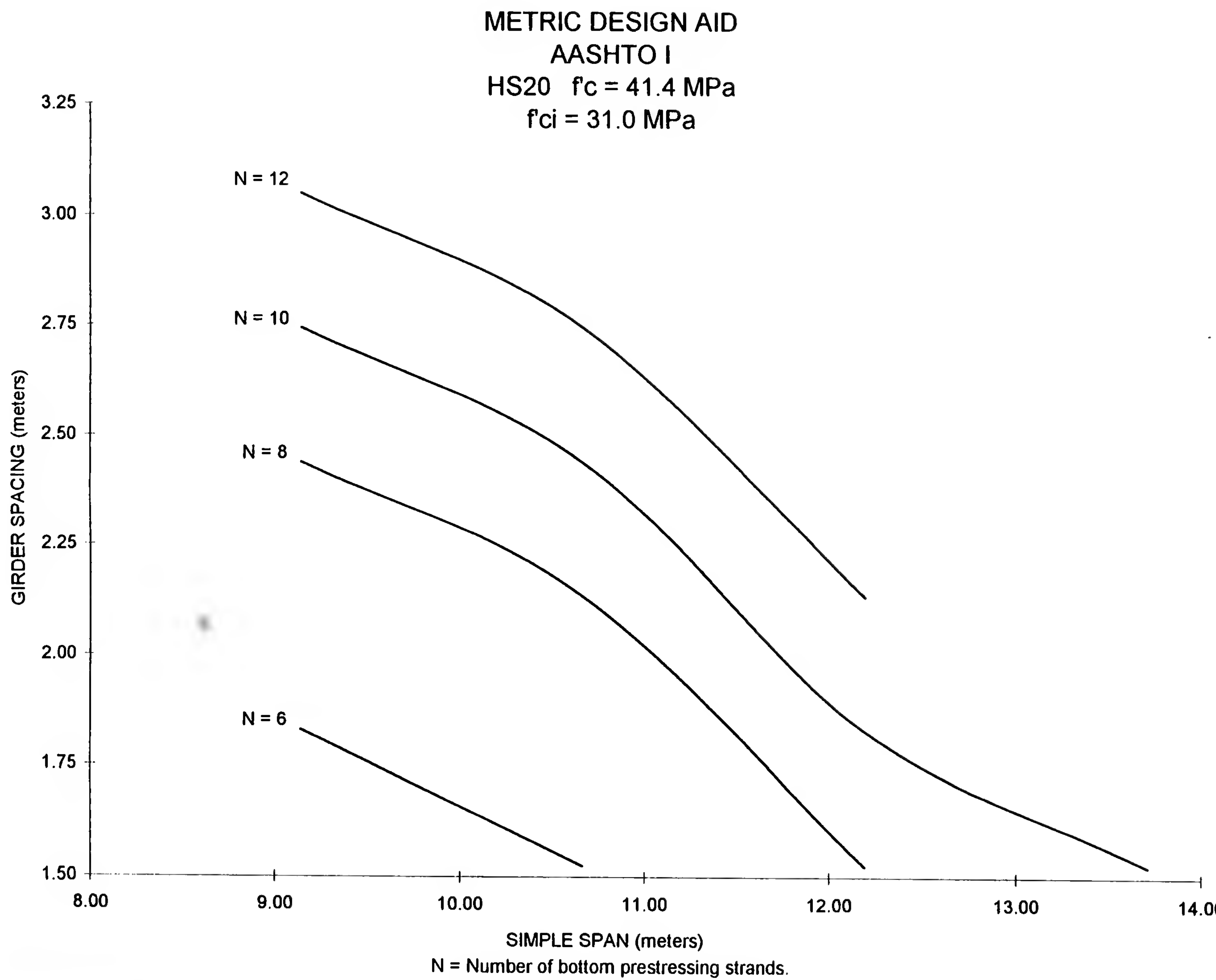
Kentucky BT 78" w/ 7" Web

HS20 f'c = 6000 psi

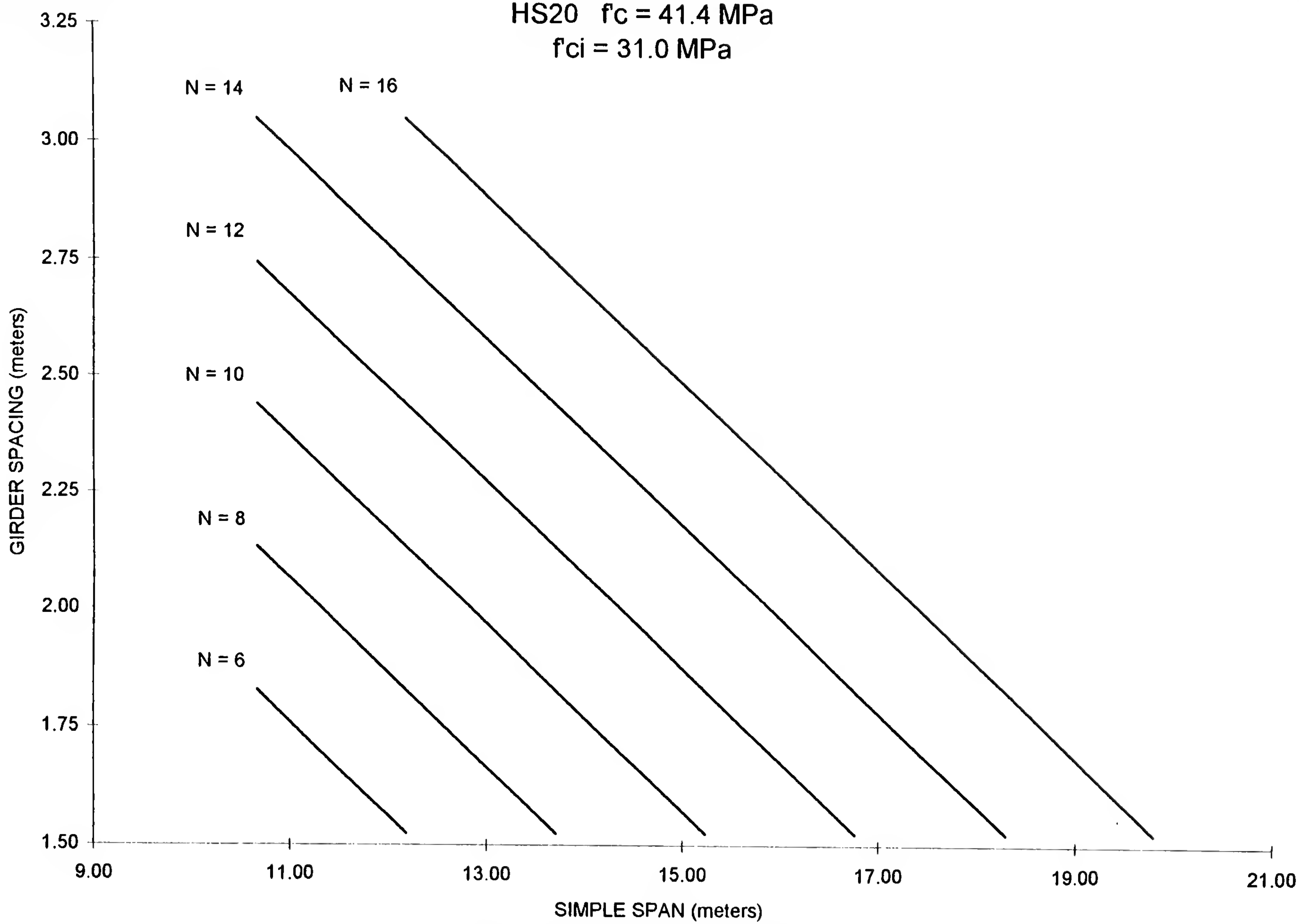
f'ci = 4500 psi



N = Number of prestressing strands.

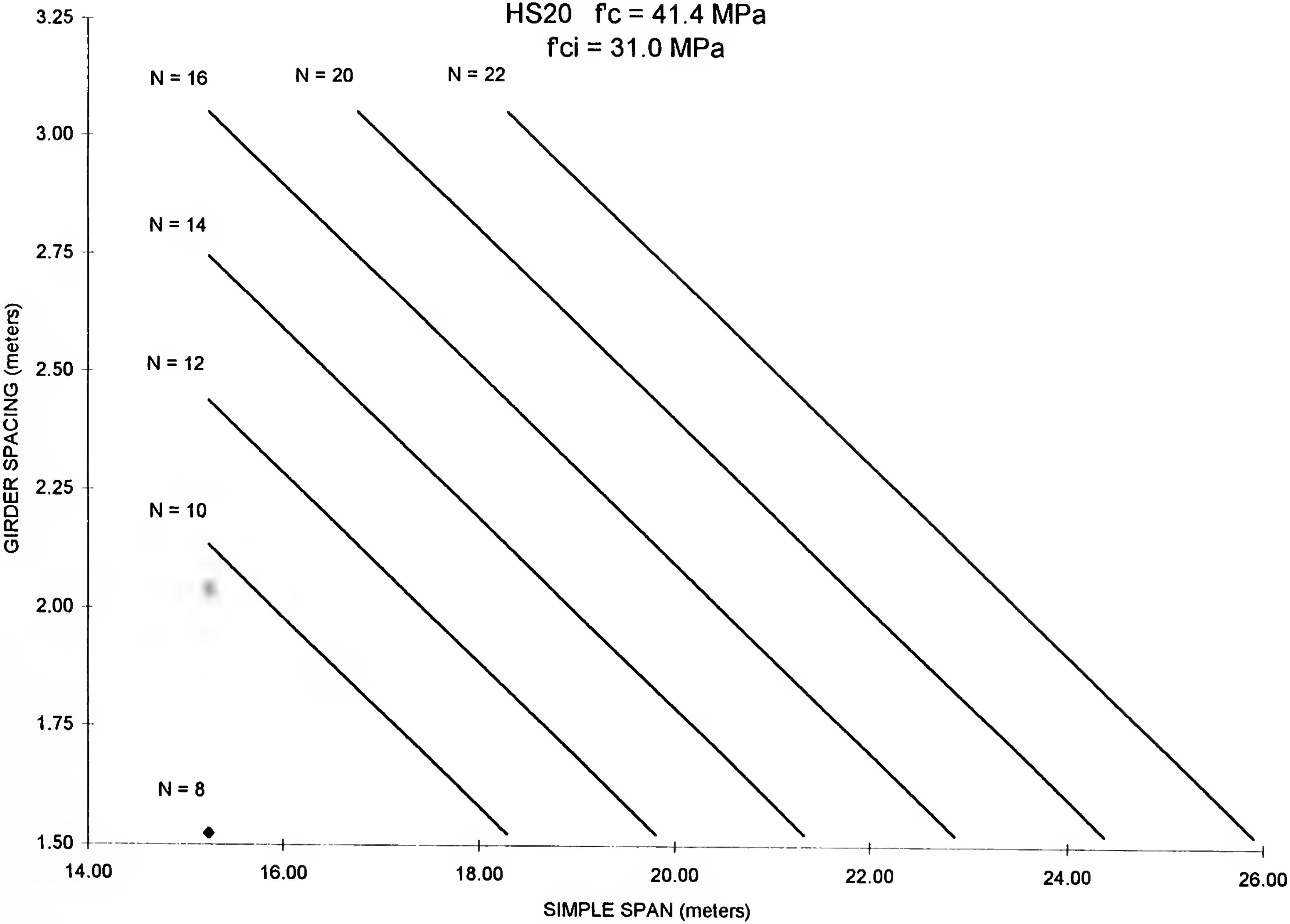

METRIC DESIGN AID
AASHTO I
HS20 f'c = 41.4 MPa
f'ci = 31.0 MPa
GIRDER SPACING (meters)
3.25
3.00
2.75
2.50
2.25
2.00
1.75
1.50
N = 12
N = 10
N = 8
N = 6
8.00
9.00
10.00
11.00
12.00
13.00
14.00
SIMPLE SPAN (meters)
N = Number of bottom prestressing strands.

METRIC DESIGN AID
AASHTO II
HS20 f'c = 41.4 MPa
f'ci = 31.0 MPa

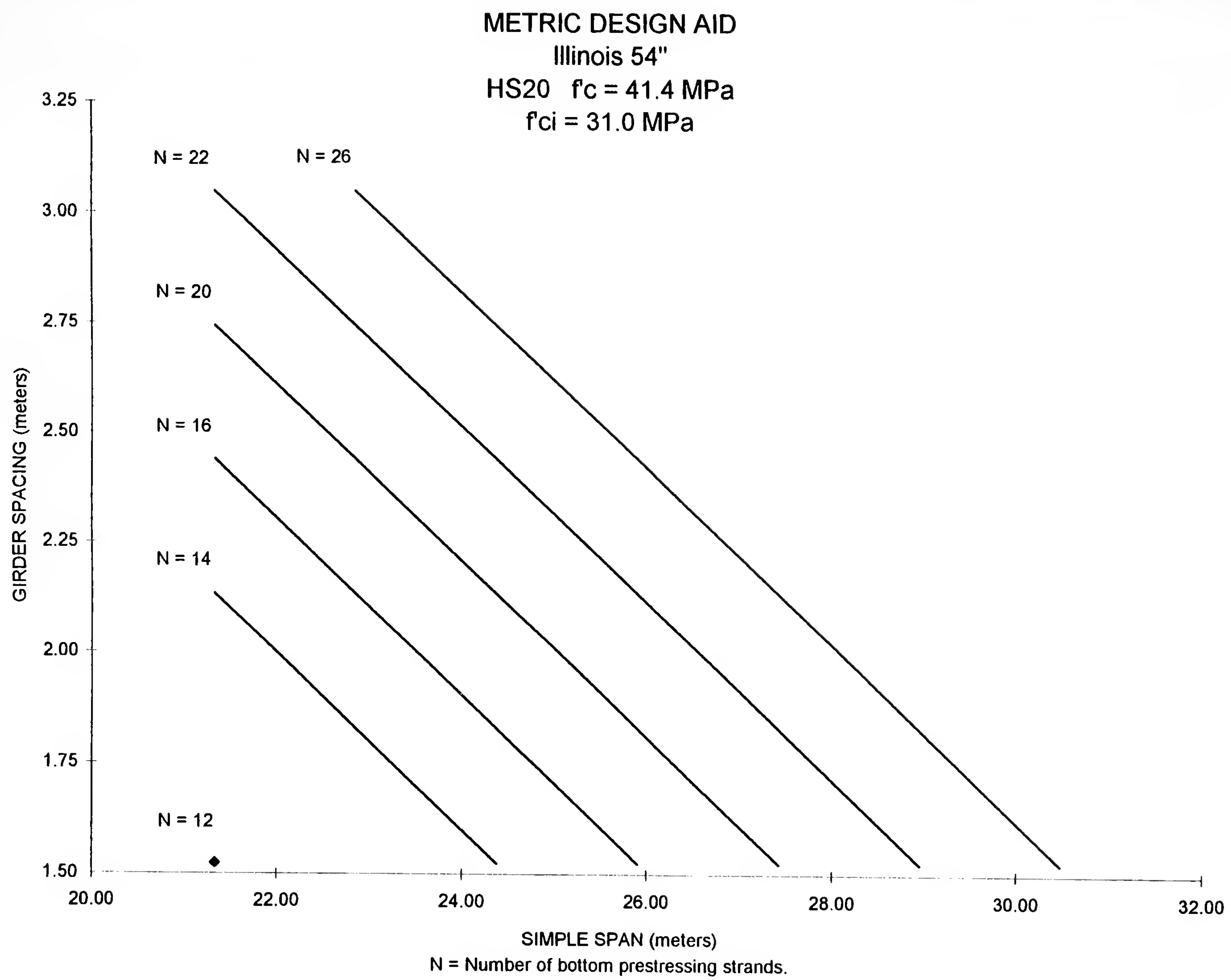


N = Number of bottom prestressing strands.

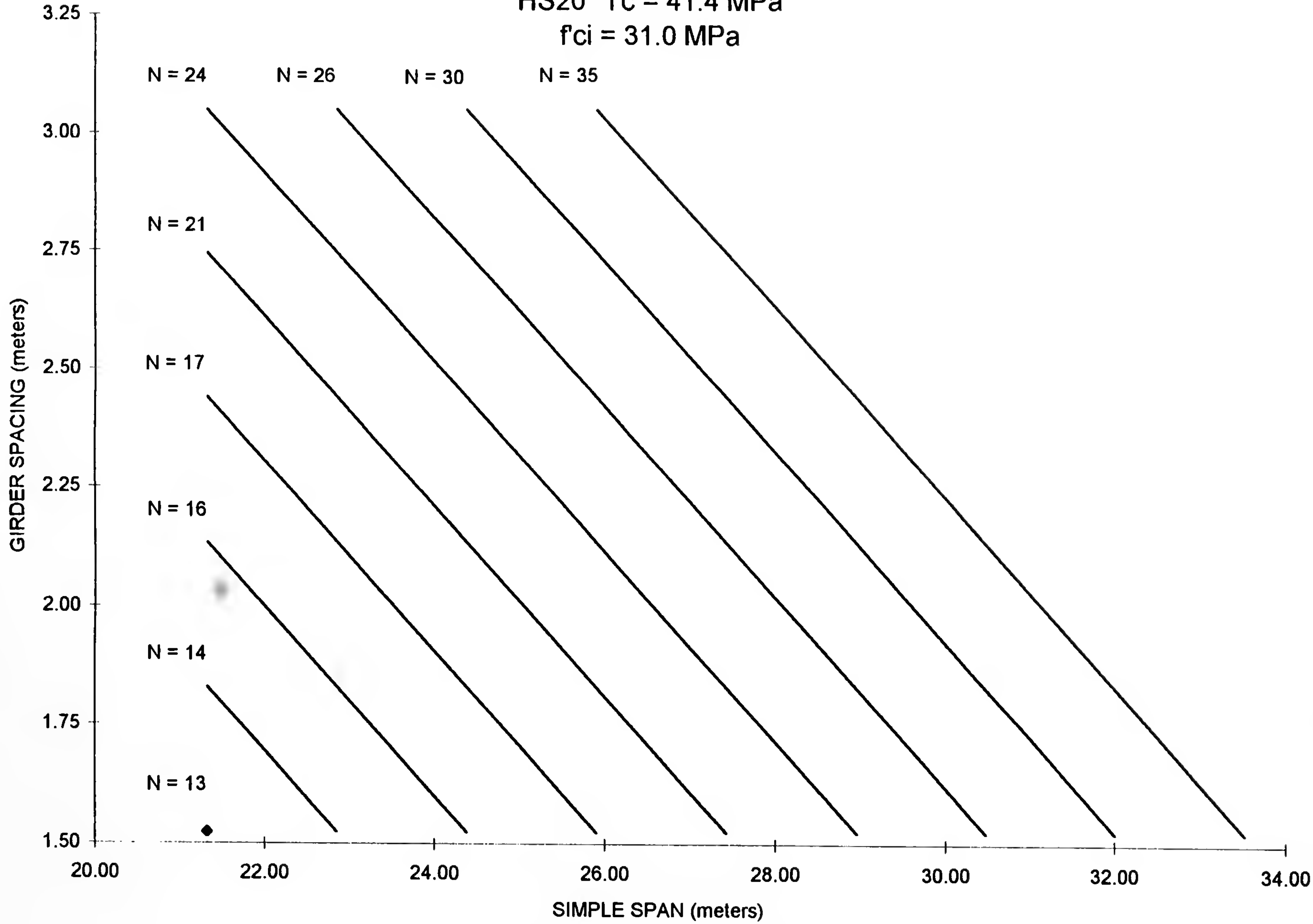
METRIC DESIGN AID
AASHTO III
HS20 f'c = 41.4 MPa
f'ci = 31.0 MPa



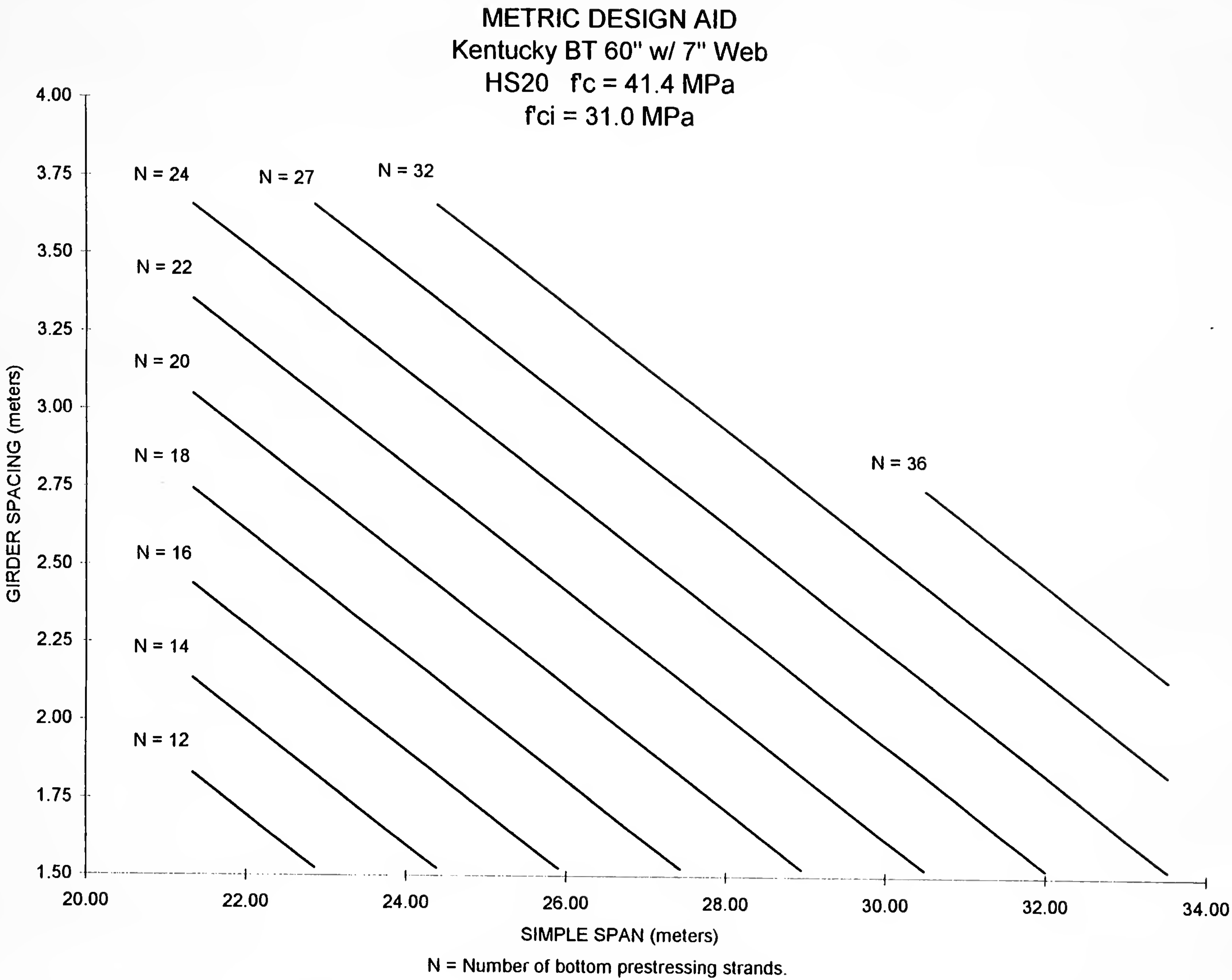
N = Number of bottom prestressing strands.


METRIC DESIGN AID
Illinois 54"
HS20 f'c = 41.4 MPa
f'ci = 31.0 MPa
GIRDER SPACING (meters)
3.25
3.00
2.75
2.50
2.25
2.00
1.75
1.50
N = 22
N = 26
N = 20
N = 16
N = 14
N = 12
20.00
22.00
24.00
26.00
28.00
30.00
32.00
SIMPLE SPAN (meters)
N = Number of bottom prestressing strands.

METRIC DESIGN AID
AASHTO IV
HS20   f'c = 41.4 MPa
f'ci = 31.0 MPa

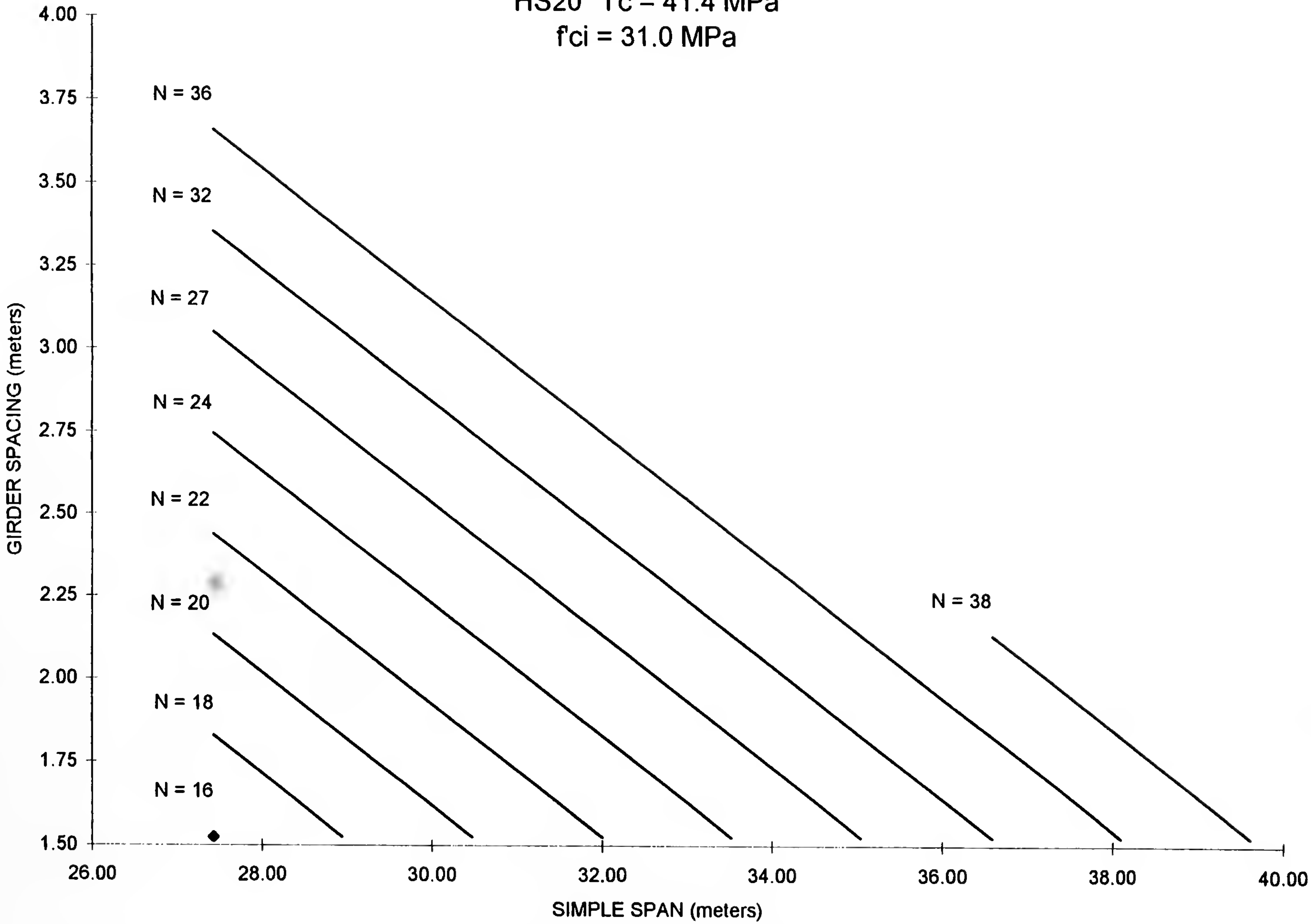


N = Number of bottom prestressing stands.

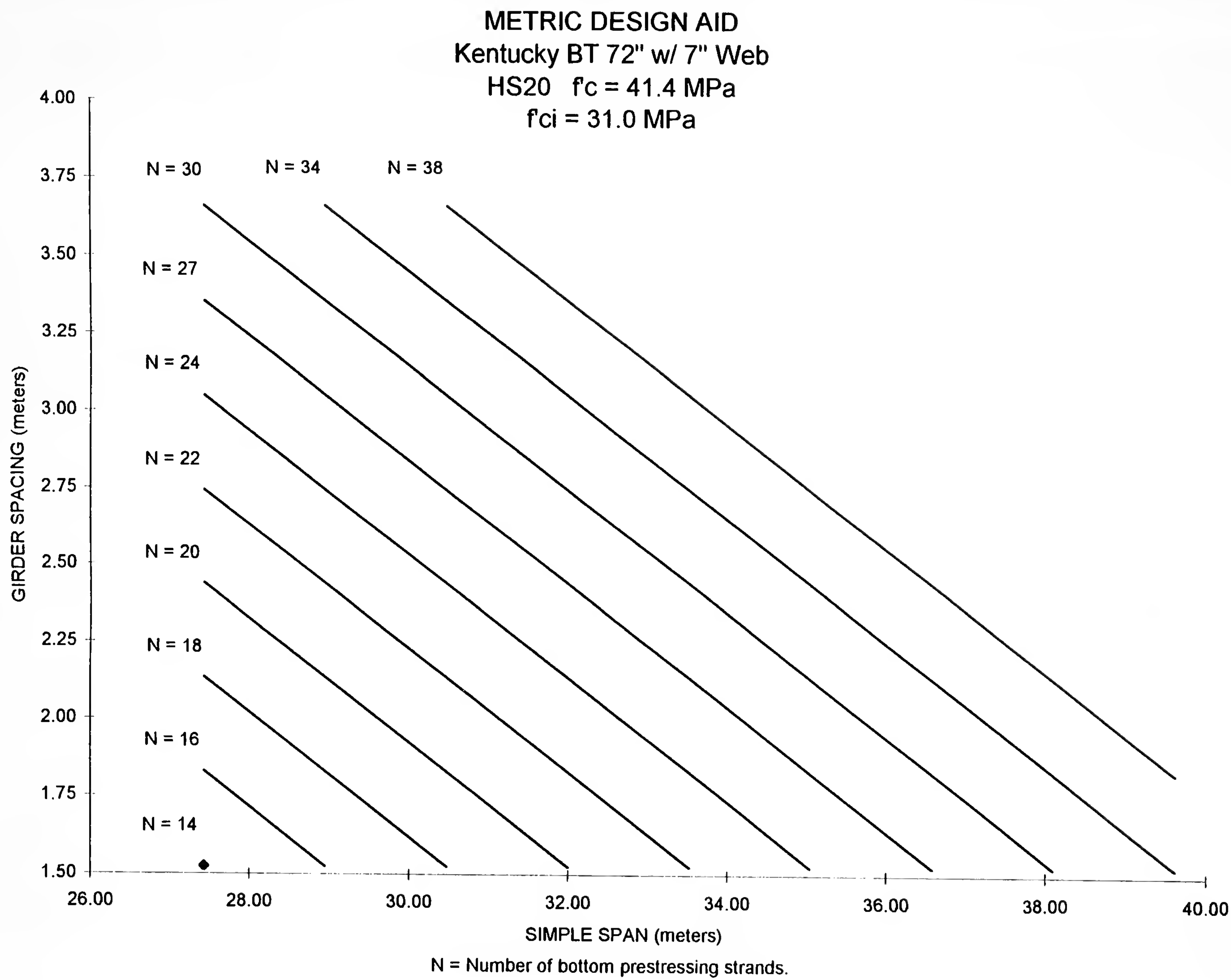


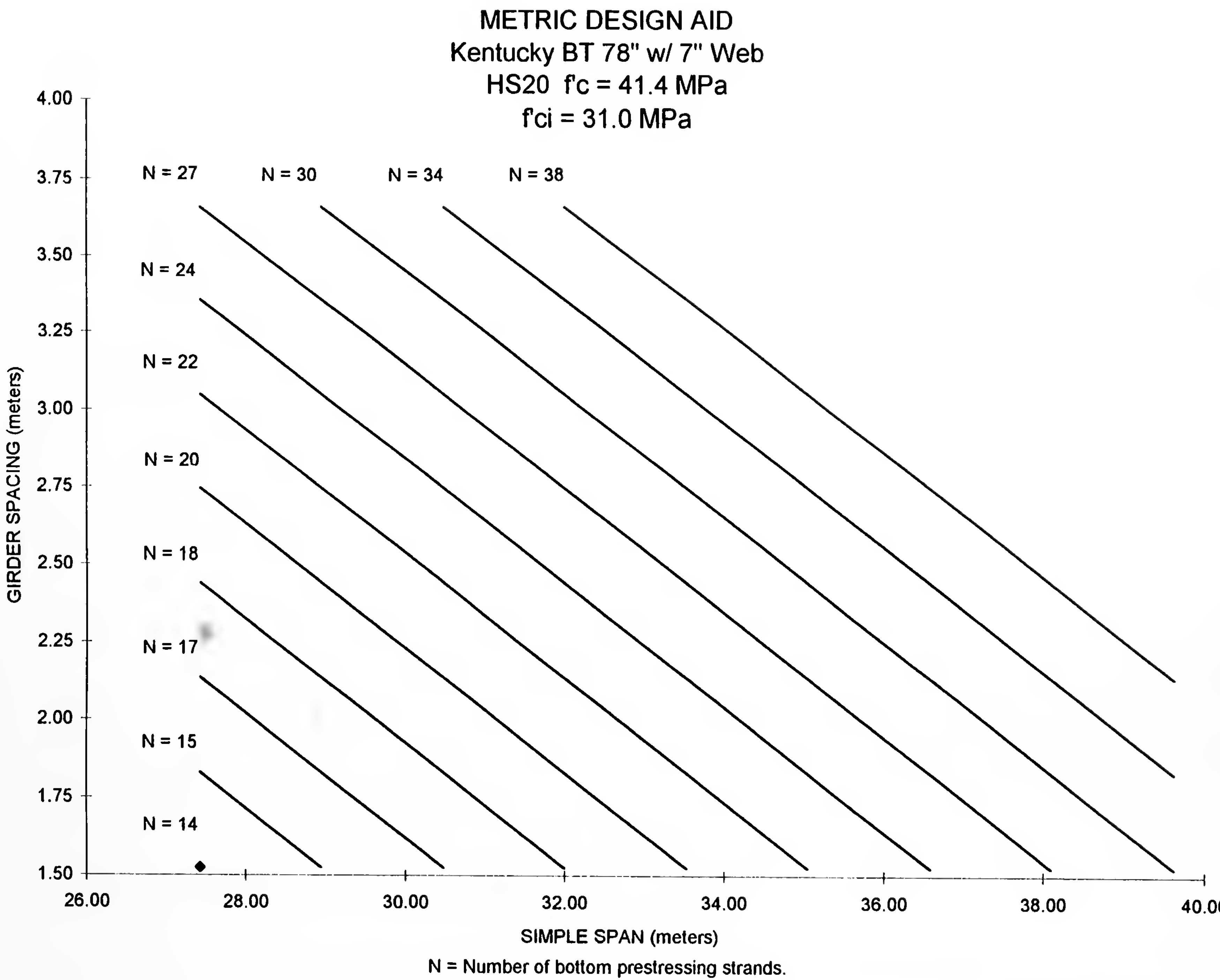
METRIC DESIGN AID
Kentucky BT 60" w/ 7" Web
HS20 f'c = 41.4 MPa
f'ci = 31.0 MPa
GIRDER SPACING (meters)
4.00
3.75
3.50
3.25
3.00
2.75
2.50
2.25
2.00
1.75
1.50
N = 24
N = 27
N = 32
N = 22
N = 20
N = 18
N = 16
N = 14
N = 12
N = 36
20.00
22.00
24.00
26.00
28.00
30.00
32.00
34.00
SIMPLE SPAN (meters)
N = Number of bottom prestressing strands.

METRIC DESIGN AID
Kentucky BT 66" w/ 7" Web
HS20   f'c = 41.4 MPa
f'ci = 31.0 MPa



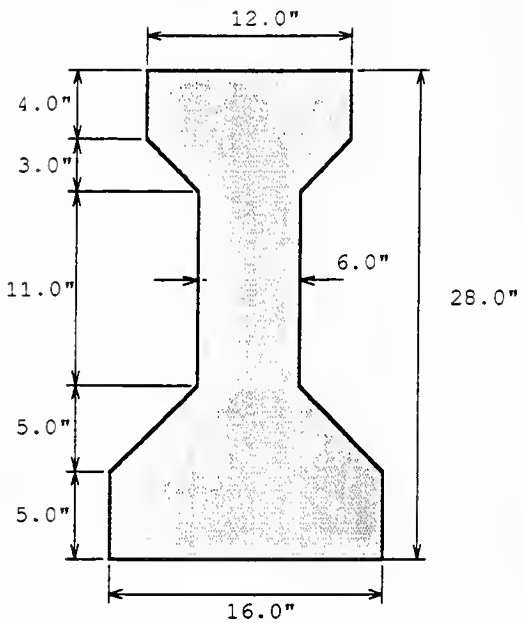
N = Number of bottom prestressing strands.


METRIC DESIGN AID
Kentucky BT 72" w/ 7" Web
HS20 f'c = 41.4 MPa
f'ci = 31.0 MPa
N = 30
N = 34
N = 38
N = 27
N = 24
N = 22
N = 20
N = 18
N = 16
N = 14
GIRDER SPACING (meters)
4.00
3.75
3.50
3.25
3.00
2.75
2.50
2.25
2.00
1.75
1.50
26.00
28.00
30.00
32.00
34.00
36.00
38.00
40.00
SIMPLE SPAN (meters)
N = Number of bottom prestressing strands.


METRIC DESIGN AID
Kentucky BT 78" w/ 7" Web
HS20 f'c = 41.4 MPa
f'ci = 31.0 MPa
N = 27
N = 30
N = 34
N = 38
N = 24
N = 22
N = 20
N = 18
N = 17
N = 15
N = 14
GIRDER SPACING (meters)
4.00
3.75
3.50
3.25
3.00
2.75
2.50
2.25
2.00
1.75
1.50
26.00
28.00
30.00
32.00
34.00
36.00
38.00
40.00
SIMPLE SPAN (meters)
N = Number of bottom prestressing strands.

Appendix I

AASHTO TYPE I



Girder Section Properties

A	=	276.00 in^2
I	=	22,744.00 in^4
Sb	=	1,807.00 in^3
St	=	1,476.00 in^3
Yb	=	12.59 in
Yt	=	15.41 in
f'c	=	6,000 psi
f'ci	=	4,500 psi

Strand Properties

Seven-Wire Special Low-Lax Strands

A	=	0.167 in^2
fpu	=	270,000 psi

Deck Properties

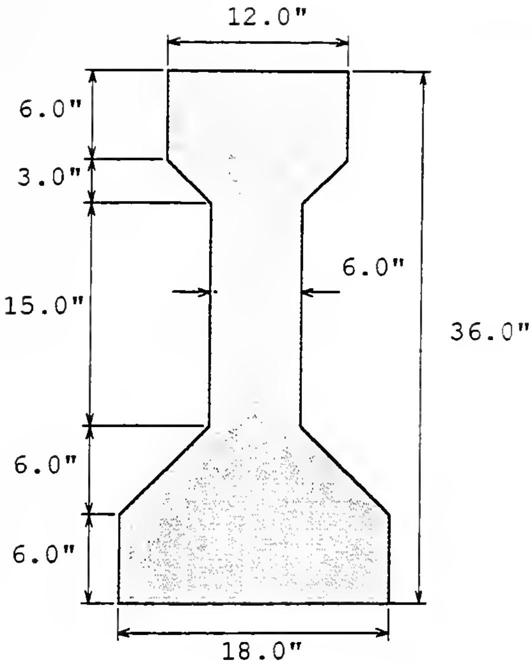
Slab	=	6.50 in
Top	=	1.50 in
f'c	=	4,000 psi
fy	=	60,000 psi

Design Table

All straight strands, no draping.

Strands	Bottom Rows				Top Rows		Maximum	Maximum
Required	1	2	3	4	1T	2T	Span (feet)	Span (meters)
N = 6	6				2		35	10.7
N = 8	6	2			2		40	12.2
N = 10	6	4			2		45	13.7
N = 12	6	6			2		40	12.2

AASHTO TYPE II



Girder Section Properties

A	=	369.00 in^2
I	=	50,979.00 in^4
Sb	=	3,221.00 in^3
St	=	2,527.00 in^3
Yb	=	15.83 in
Yt	=	20.17 in
f'c	=	6,000 psi
f'ci	=	4,500 psi

Strand Properties

Seven-Wire Special Low-Lax Strands

A	=	0.167 in^2
fpu	=	270,000 psi

Deck Properties

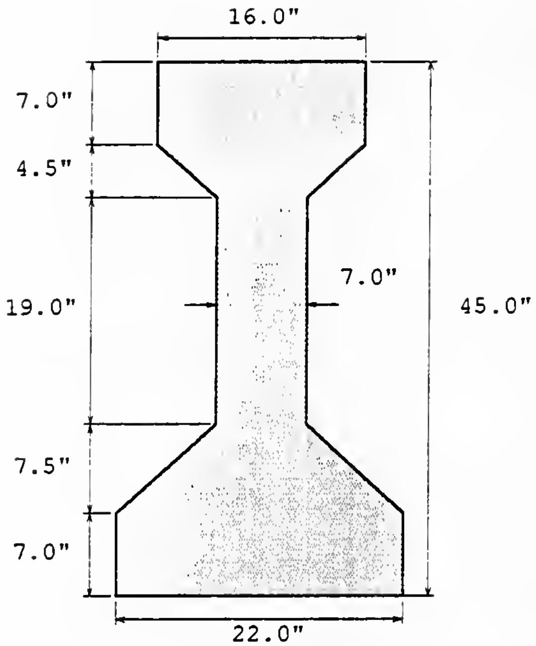
Slab	=	6.50 in
Top	=	1.50 in
f'c	=	4,000 psi
fy	=	60,000 psi

Design Table

All straight strands, no draping.

Strands	Bottom Rows				Top Rows		Maximum	Maximum
Required	1	2	3	4	1T	2T	Span (feet)	Span (meters)
N = 6	6				2		40	12.2
N = 8	8				2		45	13.7
N = 10	8	2			2		50	15.2
N = 12	8	4			2		55	16.8
N = 14	8	6			2		60	18.3
N = 16	8	8			3		65	19.8

AASHTO TYPE III



Girder Section Properties

A	=	560.00 in^2
I	=	125,390.00 in^4
Sb	=	6,185.00 in^3
St	=	5,071.00 in^3
Yb	=	20.27 in
Yt	=	24.73 in
f'c	=	6,000 psi
f'ci	=	4,500 psi

Strand Properties

Seven-Wire Special Low-Lax Strands

A	=	0.167 in^2
fpu	=	270,000 psi

Deck Properties

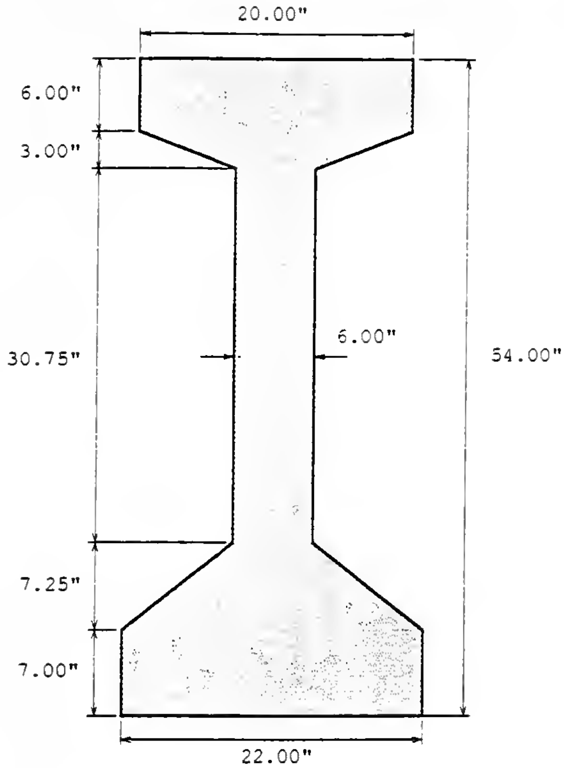
Slab	=	6.50 in
Top	=	1.50 in
f'c	=	4,000 psi
fy	=	60,000 psi

Design Table

All straight strands, no draping.

Strands	Bottom Rows				Top Rows		Maximum	Maximum
Required	1	2	3	4	1T	2T	Span (feet)	Span (meters)
N = 8	8				2		50	15.2
N = 10	10				2		60	18.3
N = 12	10	2			2		65	19.8
N = 14	10	4			2		70	21.3
N = 16	10	6			2		75	22.9
N = 20	10	10			2		80	24.4
N = 22	10	10	2		3		85	25.9

ILLINOIS 54"



Girder Section Properties

A	=	599.00 in^2
I	=	213,721.00 in^4
Sb	=	8,559.00 in^3
St	=	7,362.00 in^3
Yb	=	24.97 in
Yt	=	29.03 in
f'c	=	6,000 psi
f'ci	=	4,500 psi

Strand Properties

Seven-Wire Special Low-Lax Strands

A	=	0.167 in^2
fpu	=	270,000 psi

Deck Properties

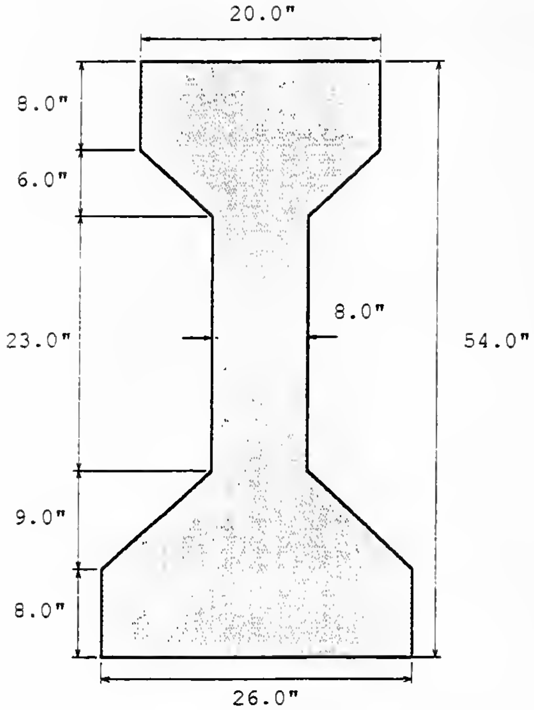
Slab	=	6.50 in
Top	=	1.50 in
f'c	=	4,000 psi
fy	=	60,000 psi

Design Table

All straight strands, no draping.

Strands Required	Bottom Rows 1	2	3	4	Top Rows 1T	2T	Maximum Span (feet)	Maximum Span (meters)
N = 12	10	2			2		70	21.3
N = 14	10	4			2		80	24.4
N = 16	10	6			2		85	25.9
N = 20	10	10			2		90	27.4
N = 22	10	10	2		2		95	29.0
N = 26	10	10	6		3		100	30.5

AASHTO TYPE IV



Girder Section Properties

A	=	789.00 in^2
I	=	260,741.00 in^4
Sb	=	10,542.00 in^3
St	=	8,909.00 in^3
Yb	=	24.73 in
Yt	=	29.27 in
f'c	=	6,000 psi
f'ci	=	4,500 psi

Strand Properties

Seven-Wire Special Low-Lax Strands

A	=	0.167 in^2
fpu	=	270,000 psi

Deck Properties

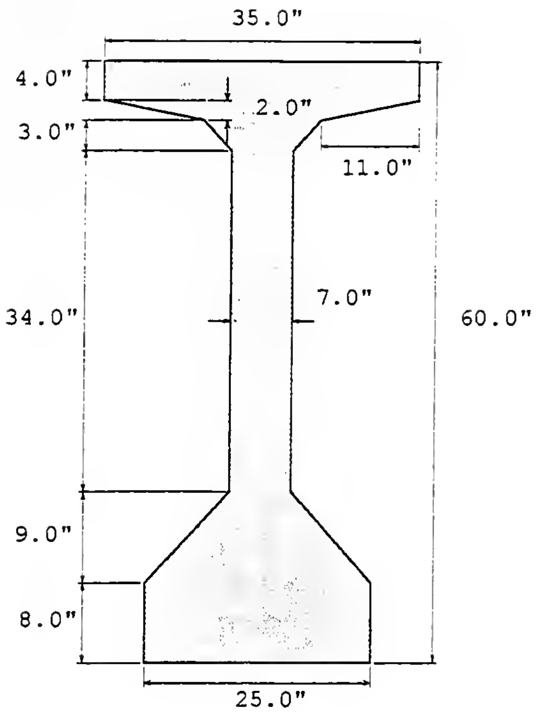
Slab	=	6.50 in
Top	=	1.50 in
f'c	=	4,000 psi
fy	=	60,000 psi

Design Table

All straight strands, no draping.

Strands	Bottom Rows				Top Rows		Maximum	Maximum
Required	1	2	3	4	1T	2T	Span (feet)	Span (meters)
N = 13	11	2			2		70	21.3
N = 14	11	3			2		75	22.9
N = 16	11	5			2		80	24.4
N = 17	11	6			2		85	25.9
N = 21	11	10			2		90	27.4
N = 24	11	11	2		2		95	29.0
N = 26	11	11	4		2		100	30.5
N = 30	11	11	8		2		105	32.0
N = 35	11	11	11	2	3		110	33.5

KENTUCKY BT 60" w/ 7" WEB



Girder Section Properties

A	=	792.00 in^2
I	=	361,830.00 in^4
Sb	=	12,740.00 in^3
St	=	11,451.00 in^3
Yb	=	28.40 in
Yt	=	31.60 in
f'c	=	6,000 psi
f'ci	=	4,500 psi

Strand Properties

Seven-Wire Special Low-Lax Strands

A	=	0.167 in^2
fpu	=	270,000 psi

Deck Properties

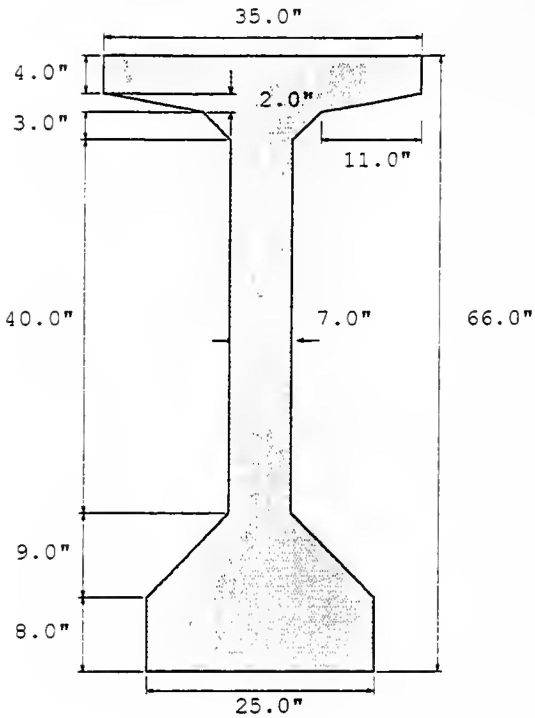
Slab	=	6.50 in
Top	=	1.50 in
f'c	=	4,000 psi
fy	=	60,000 psi

Design Table

All straight strands, no draping.

Strands	Bottom Rows				Top Rows		Maximum	Maximum
Required	1	2	3	4	1T	2T	Span (feet)	Span (meters)
N = 12	10	2			2		75	22.9
N = 14	10	4			2		80	24.4
N = 16	10	6			2		85	25.9
N = 18	10	8			2		90	27.4
N = 20	10	10			2		95	29.0
N = 22	10	10	2		2		100	30.5
N = 24	10	10	4		2		105	32.0
N = 27	10	10	7		2		110	33.5
N = 32	10	10	10	2	2		110	33.5
N = 36	10	10	10	6	3		110	33.5

KENTUCKY BT 66" w/ 7" WEB



Girder Section Properties

A	=	834.00 in^2
I	=	462,009.00 in^4
Sb	=	14,807.00 in^3
St	=	13,276.00 in^3
Yb	=	31.20 in
Yt	=	34.80 in
f'c	=	6,000 psi
f'ci	=	4,500 psi

Strand Properties

Seven-Wire Special Low-Lax Strands

A	=	0.167 in^2
fpu	=	270,000 psi

Deck Properties

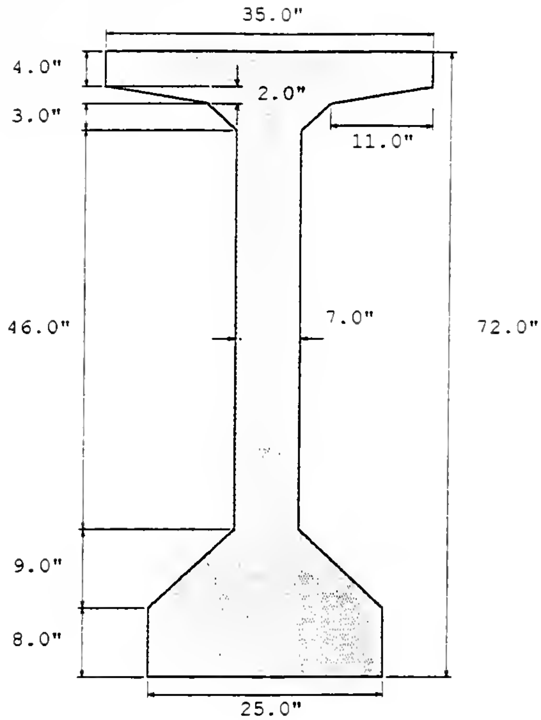
Slab	=	6.50 in
Top	=	1.50 in
f'c	=	4,000 psi
fy	=	60,000 psi

Design Table

All straight strands, no draping.

Strands	Bottom Rows				Top Rows		Maximum	Maximum
Required	1	2	3	4	1T	2T	Span (feet)	Span (meters)
N = 16	10	6			2		90	27.4
N = 18	10	8			2		95	29.0
N = 20	10	10			2		100	30.5
N = 22	10	10	2		2		105	32.0
N = 24	10	10	4		2		110	33.5
N = 27	10	10	7		2		115	35.1
N = 32	10	10	10	2	2		120	36.6
N = 36	10	10	10	6	3		125	38.1
N = 38	10	10	10	8	3		130	39.6

KENTUCKY BT 72" w/ 7" WEB



Girder Section Properties

A	=	876.00 in^2
I	=	577,140.00 in^4
Sb	=	16,965.00 in^3
St	=	15,196.00 in^3
Yb	=	34.02 in
Yt	=	37.98 in
f'c	=	6,000 psi
f'ci	=	4,500 psi

Strand Properties

Seven-Wire Special Low-Lax Strands

A	=	0.167 in^2
fpu	=	270,000 psi

Deck Properties

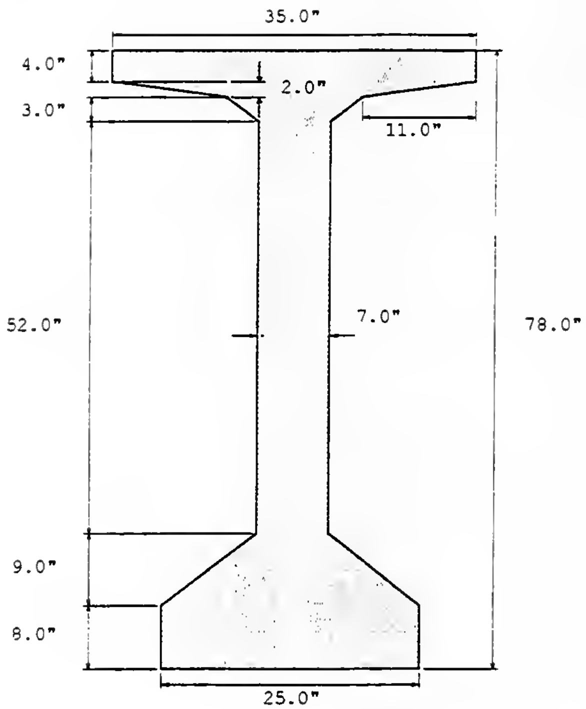
Slab	=	6.50 in
Top	=	1.50 in
f'c	=	4,000 psi
fy	=	60,000 psi

Design Table

All straight strands, no draping.

Strands	Bottom Rows					Top Rows		Maximum	Maximum
Required	1	2	3	4	5	1T	2T	Span (feet)	Span (meters)
N = 14	10	4				2		90	27.4
N = 16	10	6				2		95	29.0
N = 18	10	8				2		100	30.5
N = 20	10	10				2		105	32.0
N = 22	10	10	2			2		110	33.5
N = 24	10	10	4			2		115	35.1
N = 27	10	10	7			2		120	36.6
N = 30	10	10	10			2		125	38.1
N = 34	10	10	10	4		2		130	39.6
N = 38	10	10	10	8		2		130	39.6

KENTUCKY BT 78" w/ 7" WEB



Girder Section Properties

A	=	918.00 in^2
I	=	707,986.00 in^4
Sb	=	19,210.00 in^3
St	=	17,208.00 in^3
Yb	=	36.86 in
Yt	=	41.14 in
f'c	=	6,000 psi
f'ci	=	4,500 psi

Strand Properties

Seven-Wire Special Low-Lax Strands

A	=	0.167 in^2
fpu	=	270,000 psi

Deck Properties

Slab	=	6.50 in
Top	=	1.50 in
f'c	=	4,000 psi
fy	=	60,000 psi

Design Table

All straight strands, no draping.

Strands	Bottom Rows					Top Rows		Maximum	Maximum
Required	1	2	3	4	5	1T	2T	Span (feet)	Span (meters)
N = 14	10	4				2		90	27.4
N = 15	10	5				2		95	29.0
N = 17	10	7				2		100	30.5
N = 18	10	8				2		105	32.0
N = 20	10	10				2		110	33.5
N = 22	10	10	2			2		115	35.1
N = 24	10	10	4			2		120	36.6
N = 27	10	10	7			2		125	38.1
N = 30	10	10	10			2		130	39.6
N = 34	10	10	10	4		2		130	39.6
N = 38	10	10	10	8		2		130	39.6

Appendix J

BEAM AND DECK COSTS FOR 12' SPACING

Unit Costs			
Beam Concrete (6000 psi)	50	$/cyd	
Strands	0.30	c/ft	
Stirrups	0.45	c/lb	#4 bars. Estimated length is 2 * height + 2.3 * top flange width.
End Straps	0.45	c/lb	#3 bars at 12 in. for twice the beam depth at each end. Estimated length is 2.3 * bottom flange
Beam Mild Reinf.	0.45	c/lb	assume 2 #6 bars
Additional Costs	250	$/cyd	beam volume only
BEAM SPACING	12	FEET	

BEAM TYPES	SPANS (ft)	Eff. SPAN	DECK COSTS From INDOT Chart $/SF	DECK COSTS From INDOT Chart $/LF	BEAM CONCRETE $/LF	ADDED COSTS $/LF	END STRAPS $/GIRDER	MILD REINF $/LF	STRANDS & STIRRUPS ($/LF) SPAN 1	STRANDS & STIRRUPS ($/LF) SPAN 2	STRANDS & STIRRUPS ($/LF) SPAN 3	STRANDS & STIRRUPS ($/LF) SPAN 4	BEAM & DECK COSTS ($/LF) SPAN 1	BEAM & DECK COSTS ($/LF) SPAN 2	BEAM & DECK COSTS ($/LF) SPAN 3	BEAM & DECK COSTS ($/LF) SPAN 4
KY 60" w/ 7" web	70-80	10.54	11.27	135.24	10.19	50.93	18.22	1.35	13.80	14.80	16.51		211.74	212.72	214.41	
KY 68" w/ 7" web	90-95	10.54	11.27	135.24	10.73	53.63	17.84	1.35	18.02	18.80			219.16	219.93		
KY 72" w/ 7" web	90-100	10.54	11.27	135.24	11.27	56.33	19.46	1.35	16.00	17.42	18.71		220.40	221.81	223.09	
KY 78" w/ 7" web	90-105	10.54	11.27	135.24	11.81	59.03	21.08	1.35	14.95	16.11	17.43	18.85	222.61	223.76	225.06	226.47

BEAM AND DECK COSTS FOR 10' SPACING

Unit Costs			
Beam Concrete (6000 psi)	50	$/cyd	
Strands	0.30	c/ft	
Stirrups	0.45	c/lb	#4 bars. Estimated length is 2 * height + 2.3 * top flange width.
End Straps	0.45	c/lb	#3 bars at 12 in. for twice the beam depth at each end. Estimated length is 2.3 * bottom flange
Beam Mild Reinf	0.45	c/lb	assume 2 #6 bars
Additional Costs	250	$/cyd	beam volume only
BEAM SPACING	**10**	**FEET**	

BEAM TYPES	SPANS (ft)	Eff. SPAN	DECK COSTS From INDOT Chart $/SF	DECK COSTS $/LF	BEAM CONCRETE $/LF	ADDED COSTS $/LF	END STRAPS $/GIRDER	MILD REINF $/LF
AASHTO I	30	9.00	10.47	104.70	3.55	17.75	4.84	1.35
AASHTO II	30-45	9.00	10.47	104.70	4.75	23.73	7.00	1.35
AASHTO III	50-65	8.67	10.47	104.70	7.20	36.01	10.70	1.35
AASHTO IV	70-85	8.33	10.17	101.70	10.15	50.73	15.18	1.35
Illinois 54"	60-75	8.33	10.17	101.7	7.70	38.52	12.84	1.35
KY 60" w/ 7" web	70-90	8.54	10.47	104.70	10.19	50.93	16.22	1.35
KY 66" w/ 7" web	90-100	8.54	10.47	104.70	10.73	53.63	17.84	1.35
KY 72" w/ 7" web	90-110	8.54	10.47	104.70	11.27	56.33	19.46	1.35
KY 78" w/ 7" web	100-115	8.54	10.47	104.70	11.81	59.03	21.08	1.35

BEAM TYPES	STRANDS & STIRRUPS ($/LF)					BEAM & DECK COSTS ($/LF)				
	SPAN 1	SPAN 2	SPAN 3	SPAN 4	SPAN 5	SPAN 1	SPAN 2	SPAN 3	SPAN 4	SPAN 5
AASHTO I	6.39					133.90				
AASHTO II	4.73	7.19	8.04	6.86		139.49	141.92	142.74	141.54	
AASHTO III	8.61	10.04	10.73	10.02		158.09	159.50	160.17	159.45	
AASHTO IV	11.94	12.74	14.02	15.67		176.09	176.87	178.14	179.78	
Illinois 54"	9.30	10.51	11.23	12.53		158.79	159.98	160.68	161.97	
KY 60" w/ 7" web	11.00	12.36	13.23	14.25	15.85	178.39	179.74	180.59	181.60	183.19
KY 66" w/ 7" web	14.25	15.88	17.29			184.85	186.47	187.88		
KY 72" w/ 7" web	13.20	14.26	15.41	16.73	18.05	187.06	188.11	189.25	190.56	191.87
KY 78" w/ 7" web	14.38	15.43	16.77	18.10		191.48	192.52	193.85	195.17	

BEAM AND DECK COSTS FOR 8' SPACING

Unit Costs			
Beam Concrete (6000 psi)	50	$/cyd	
Strands	0.30	c/ft	
Stirrups	0.45	c/lb	#4 bars. Estimated length is 2 * height + 2.3 * top flange width.
End Straps	0.45	c/lb	#3 bars at 12 in for twice the beam depth at each end. Estimated length is 2.3 * bottom flange
Beam Mild Reinf.	0.45	c/lb	assume 2 #6 bars
Additional Costs	250	$/cyd	beam volume only
BEAM SPACING	**8**	**FEET**	

BEAM TYPES	SPANS (ft)	Eff. SPAN	DECK COSTS From INDOT Chart $/SF	DECK COSTS From INDOT Chart $/LF	BEAM CONCRETE $/LF	ADDED COSTS $/LF	END STRAPS $/GIRDER	MILD REINF $/LF	STRANDS & STIRRUPS ($/LF) SPAN 1	SPAN 2	SPAN 3	SPAN 4	SPAN 5	BEAM & DECK COSTS ($/LF) SPAN 1	SPAN 2	SPAN 3	SPAN 4	SPAN 5
AASHTO I	30-35	7.00	9.69	77.52	3.55	17.75	4.84	1.35	4.77	5.51				105.10	105.82			
AASHTO II	30-50	7.00	9.69	77.52	4.75	23.73	7.00	1.35	3.63	5.42	6.22	6.97	7.69	111.21	112.97	113.74	114.47	115.18
AASHTO III	50-70	6.67	9.50	76.00	7.20	36.01	10.70	1.35	6.78	7.55	8.19	9.52	10.23	127.55	128.31	128.93	130.24	130.94
AASHTO IV	70-90	6.33	9.33	74.64	10.15	50.73	15.18	1.35	9.07	10.11	11.44	12.07	13.46	146.16	147.19	148.50	149.12	150.50
Illinois 54"	70-85	6.33	9.33	74.64	7.70	38.52	12.84	1.35	8.66	9.91	10.65	11.98		131.05	132.29	133.02	134.34	
KY 60" w/ 7" web	70-90	6.54	9.50	76.00	10.19	50.93	16.22	1.35	9.54	10.22	11.02	11.68	12.45	148.23	148.90	149.69	150.34	151.09
KY 66" w/ 7" web	90-110	6.54	9.50	76.00	10.73	53.63	17.84	1.35	11.69	12.47	13.53	15.08	16.41	153.59	154.36	155.41	156.95	158.28
KY 72" w/ 7" web	90-110	6.54	9.50	76.00	11.27	56.33	19.46	1.35	11.00	11.81	12.49	13.56	14.52	156.16	156.96	157.63	158.69	159.64
KY 78" w/ 7" web	110-130	6.54	9.50	76.00	11.81	59.03	21.08	1.35	13.59	14.56	15.93	17.28	18.52	161.97	162.93	164.29	165.63	166.87

BEAM AND DECK COSTS FOR 5' SPACING

Unit Costs		
Beam Concrete (6000 psi)	50	$/cyd
Strands	0.30	c/ft
Stirrups	0.45	c/lb
End Straps	0.45	c/lb
Beam Mild Reinf.	0.45	c/lb
Additional Costs	250	$/cyd
BEAM SPACING	**5**	**FEET**

Stirrups: #4 bars. Estimated length is 2 * height + 2.3 * top flange width
End Straps: #3 bars at 12 in for twice the beam depth at each end. Estimated length is 2.3 * bottom flange
Beam Mild Reinf.: assume 2 #6 bars
Additional Costs: beam volume only

BEAM TYPES	SPANS (ft)	Eff. SPAN	DECK COSTS From INDOT Chart $/SF	$/LF	BEAM CONCRETE $/LF	ADDED COSTS $/LF	END STRAPS $/GIRDER	MILD REINF $/LF	STRANDS & STIRRUPS ($/LF) SPAN 1	SPAN 2	SPAN 3	SPAN 4	SPAN 5	BEAM & DECK COSTS ($/LF) SPAN 1	SPAN 2	SPAN 3	SPAN 4	SPAN 5
AASHTO I	30-45	4.00	9.33	46.65	3.55	17.75	4.84	1.35	3.34	3.36	4.08	4.86		72.80	72.79	73.49	74.27	
AASHTO II	50-65	4.00	9.33	46.65	4.75	23.73	7.00	1.35	4.90	5.60	6.28	6.95		81.51	82.20	82.87	83.53	
AASHTO III	70-90	3.67	9.33	46.65	7.20	36.01	10.70	1.35	6.65	7.34	8.62	9.29	9.85	98.01	98.70	99.97	100.63	101.18
AASHTO IV	90-110	3.33	9.33	46.65	10.15	50.73	15.18	1.35	9.39	10.37	11.04	12.31	13.94	118.44	119.41	120.07	121.33	122.96
Illinois 54"	90-105	3.33	9.33	46.65	7.70	38.52	12.84	1.35	8.31	9.52	10.81	11.49		102.68	103.88	105.16	105.83	
KY 60" w/ 7" web	90-110	3.54	9.33	46.65	10.19	50.93	16.22	1.35	8.48	9.10	10.42	11.12	11.82	117.78	118.38	119.69	120.39	121.08
KY 66" w/ 7" web	90-110	3.54	9.33	46.65	10.73	53.63	17.84	1.35	11.17	11.87	12.57	13.86	15.14	123.68	124.38	125.07	126.35	127.63
KY 72" w/ 7" web	90-110	3.54	9.33	46.65	11.27	56.33	19.46	1.35	10.49	11.21	12.22	13.23	14.53	126.26	126.97	127.98	128.98	130.27
KY 78" w/ 7" web	110-130	3.54	9.33	46.65	11.81	59.03	21.08	1.35	9.88	10.62	11.25	12.27	13.28	128.90	129.64	130.26	131.27	132.28

COST SAVINGS EXAMPLES
3 SPAN 48' WIDE TYPICAL BRIDGE

EXAMPLE 1

BEAM	f'c (psi)	SPACING (feet)	SPAN (feet)	WIDTH (feet)	COST ($/sf)	TOTAL ($)
AASHTO V	6000	5	125	48	$26.68	$480,240
KENTUCKY 78"	6000	8	125	48	$20.70	$372,600
						$107,640
						22%
						SAVINGS

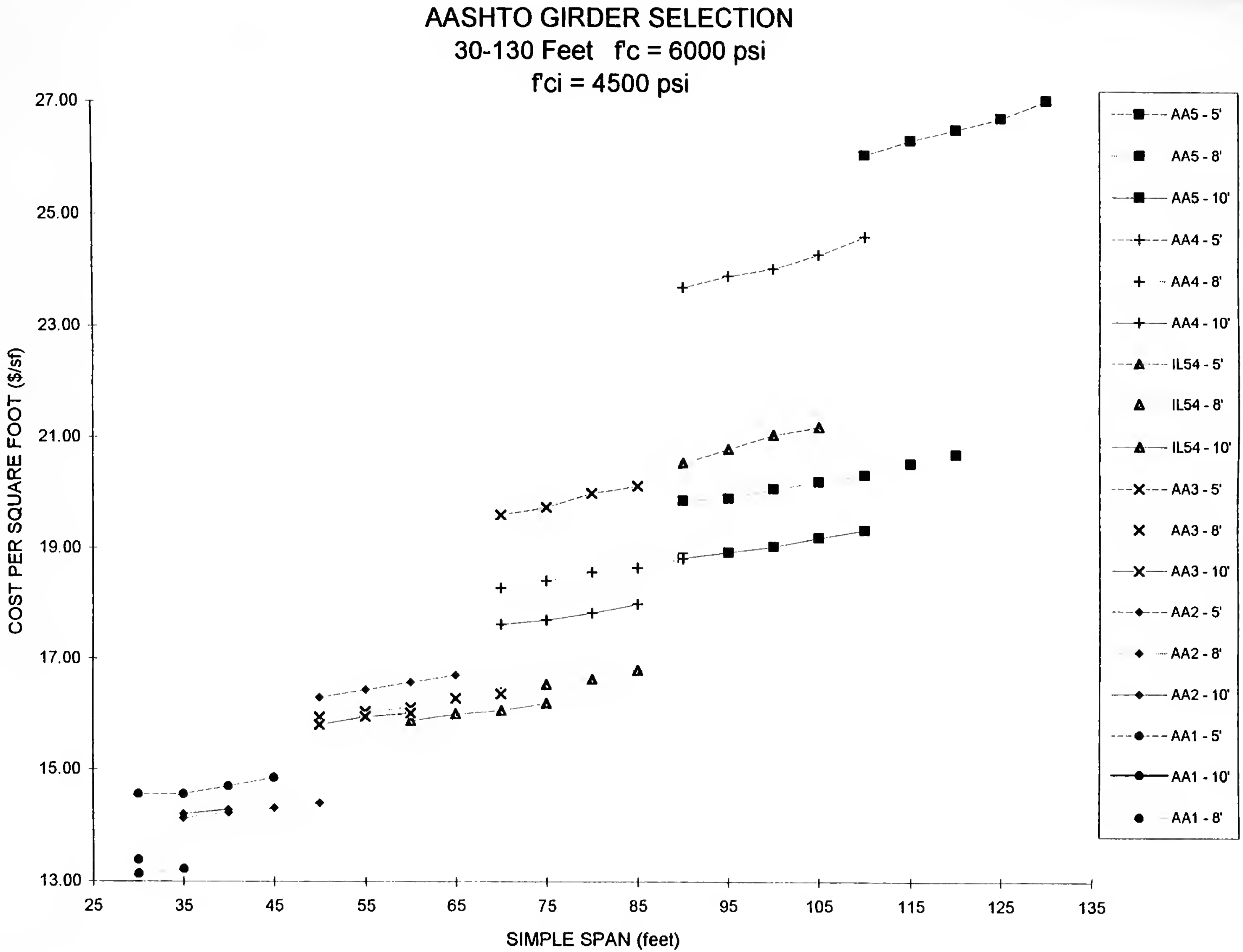
EXAMPLE 2

BEAM	f'c (psi)	SPACING (feet)	SPAN (feet)	WIDTH (feet)	COST ($/sf)	TOTAL ($)
ILLINOIS 54"	6000	5	90	48	$20.54	$266,198
KENTUCKY 60"	6000	10	90	48	$18.32	$237,427
						$28,771
						11%
						SAVINGS

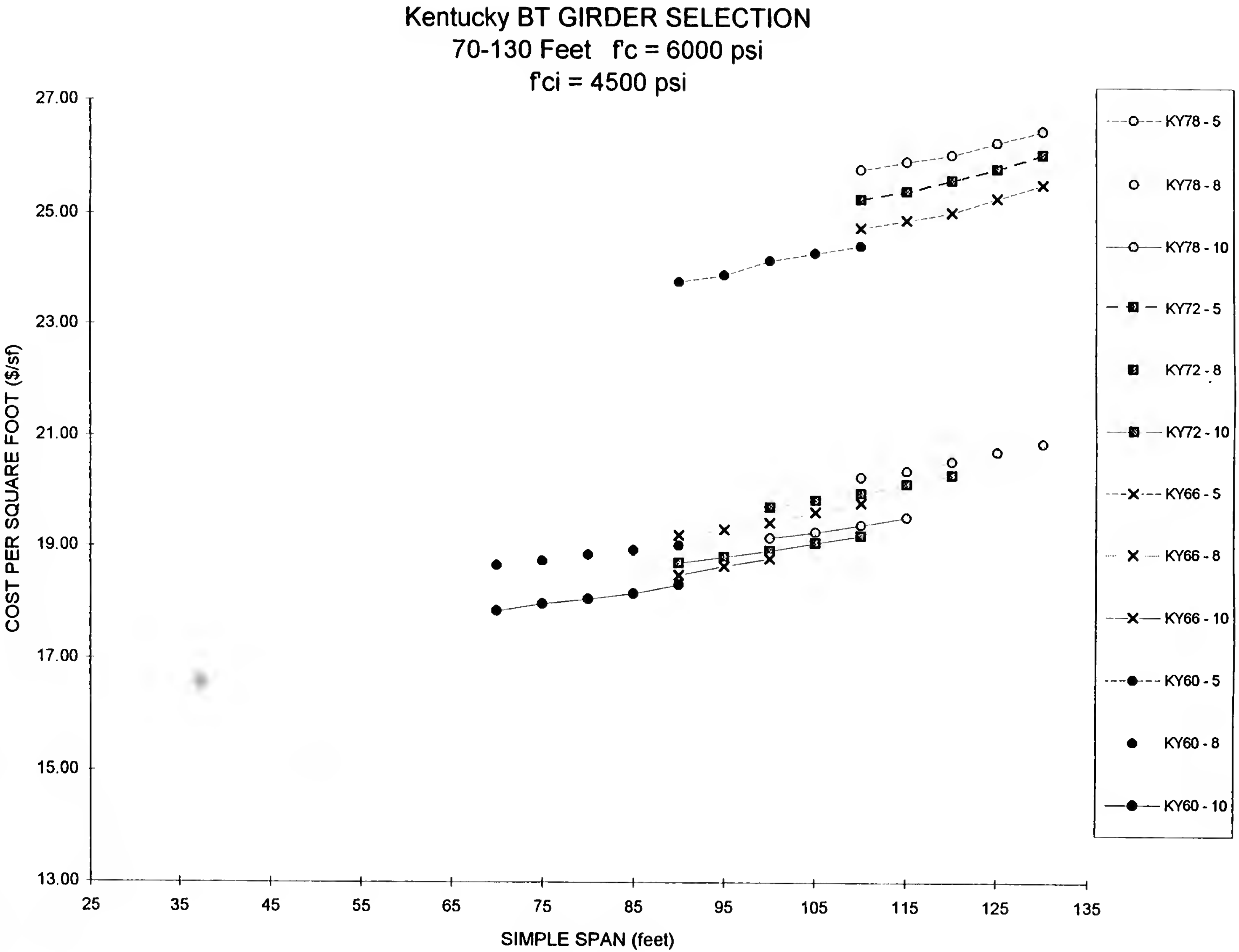
EXAMPLE 3

BEAM	f'c (psi)	SPACING (feet)	SPAN (feet)	WIDTH (feet)	COST ($/sf)	TOTAL ($)
AASHTO V	6000	10	90	48	$18.82	$243,907
KENTUCKY 60"	6000	10	90	48	$18.32	$237,427
						$6,480
						3%
						SAVINGS

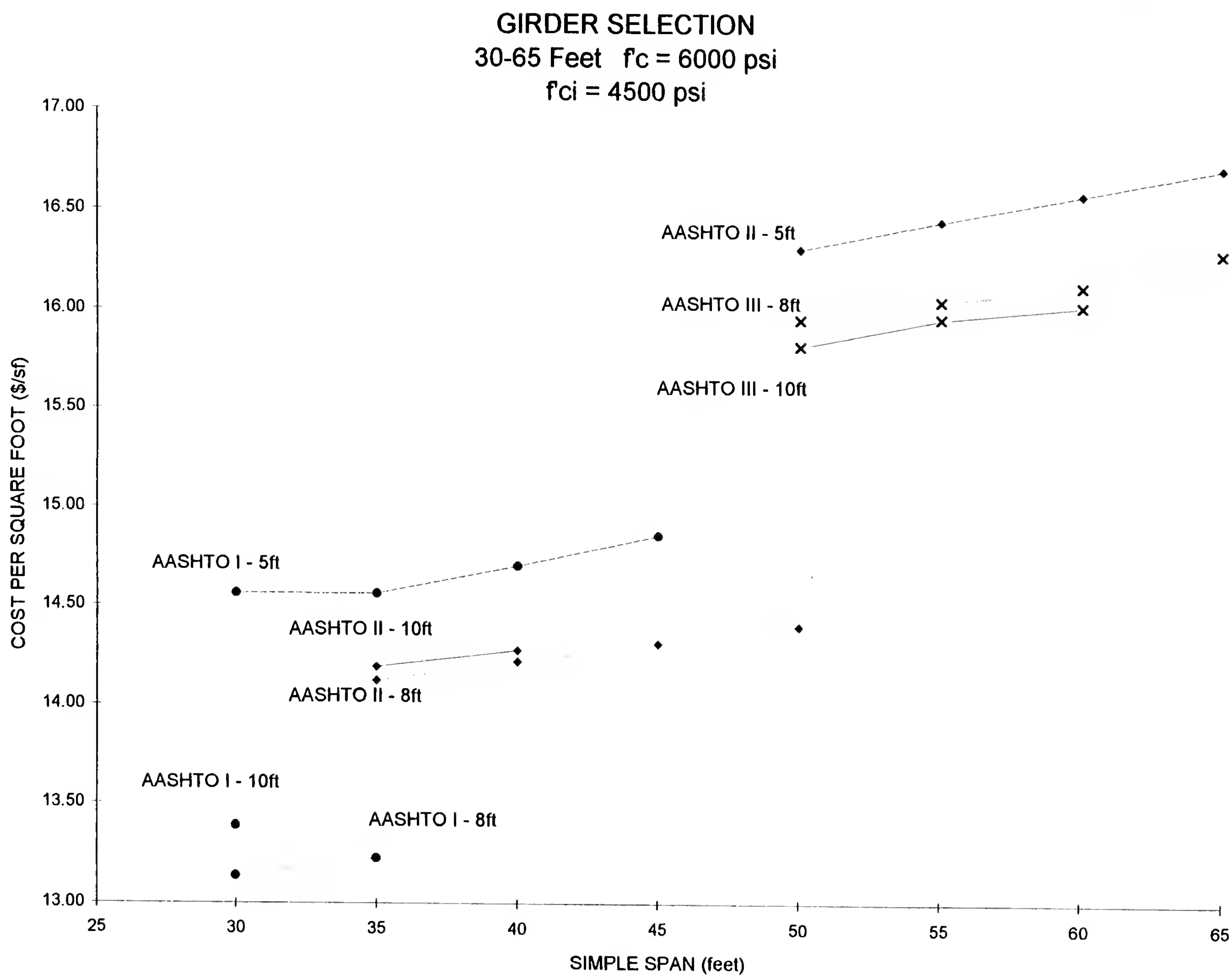
Note: Costs are for superstructure only (beam and deck)

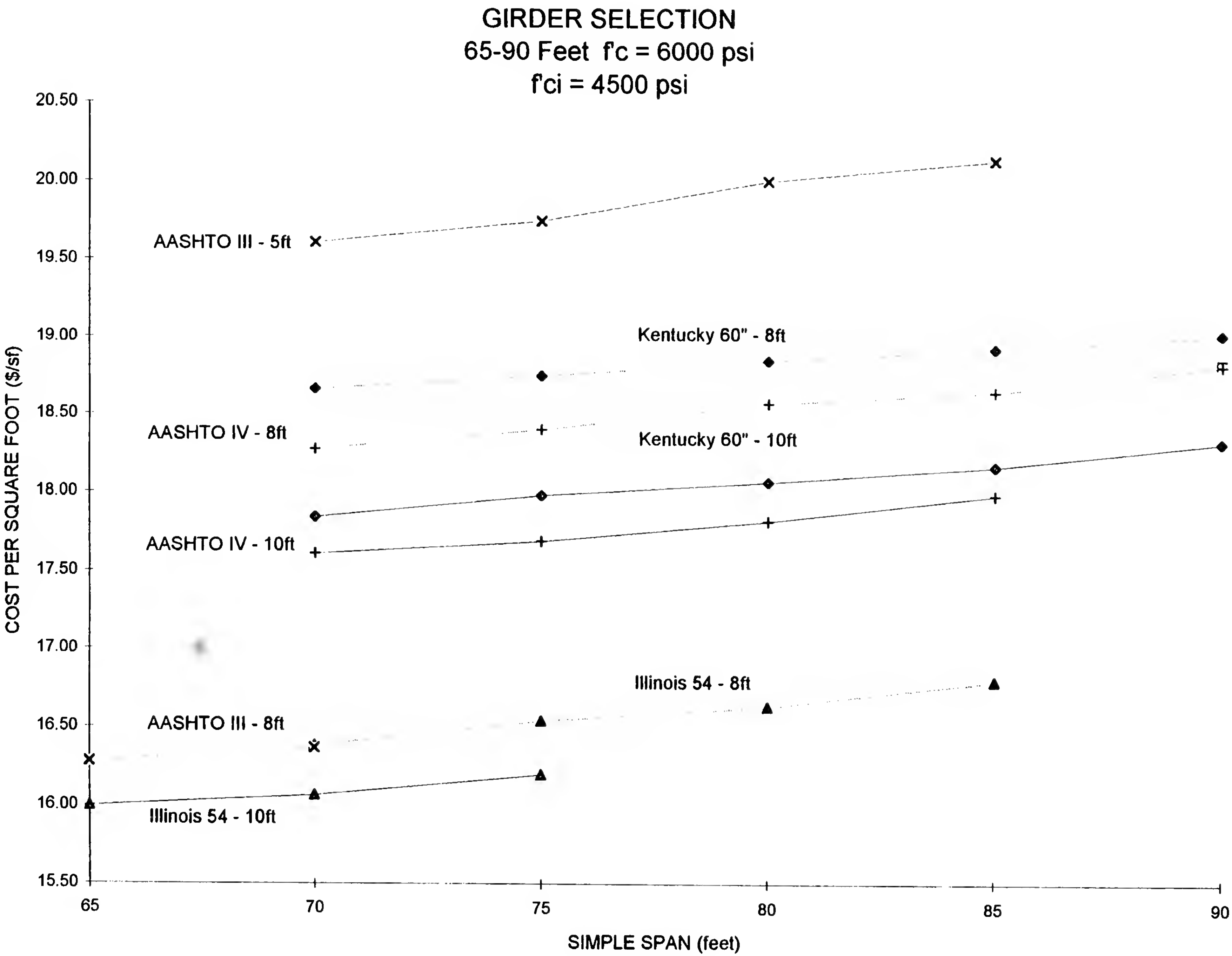


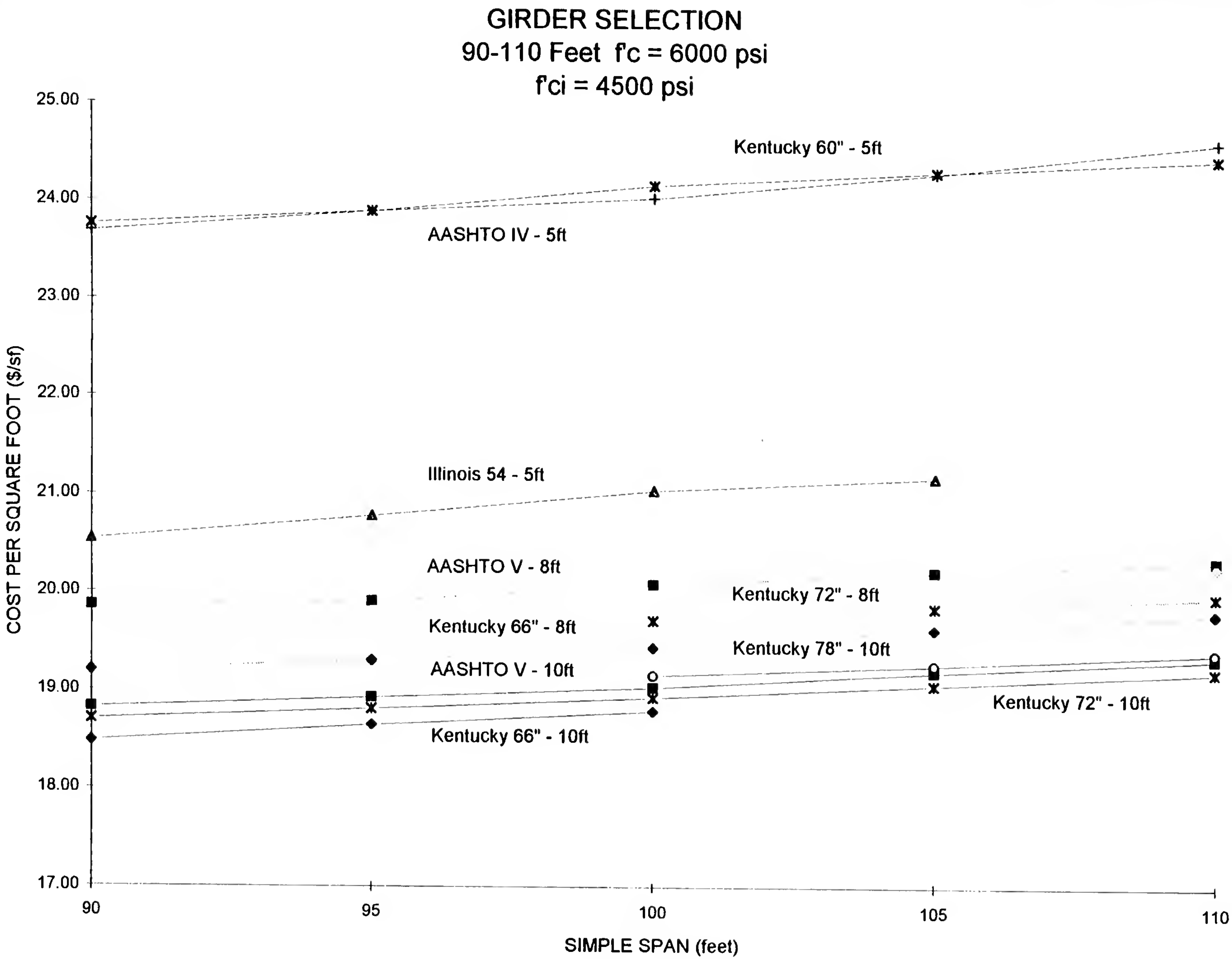
Beam spans may increase 5 to 10 feet when using 7000 psi concrete or continuous spans.

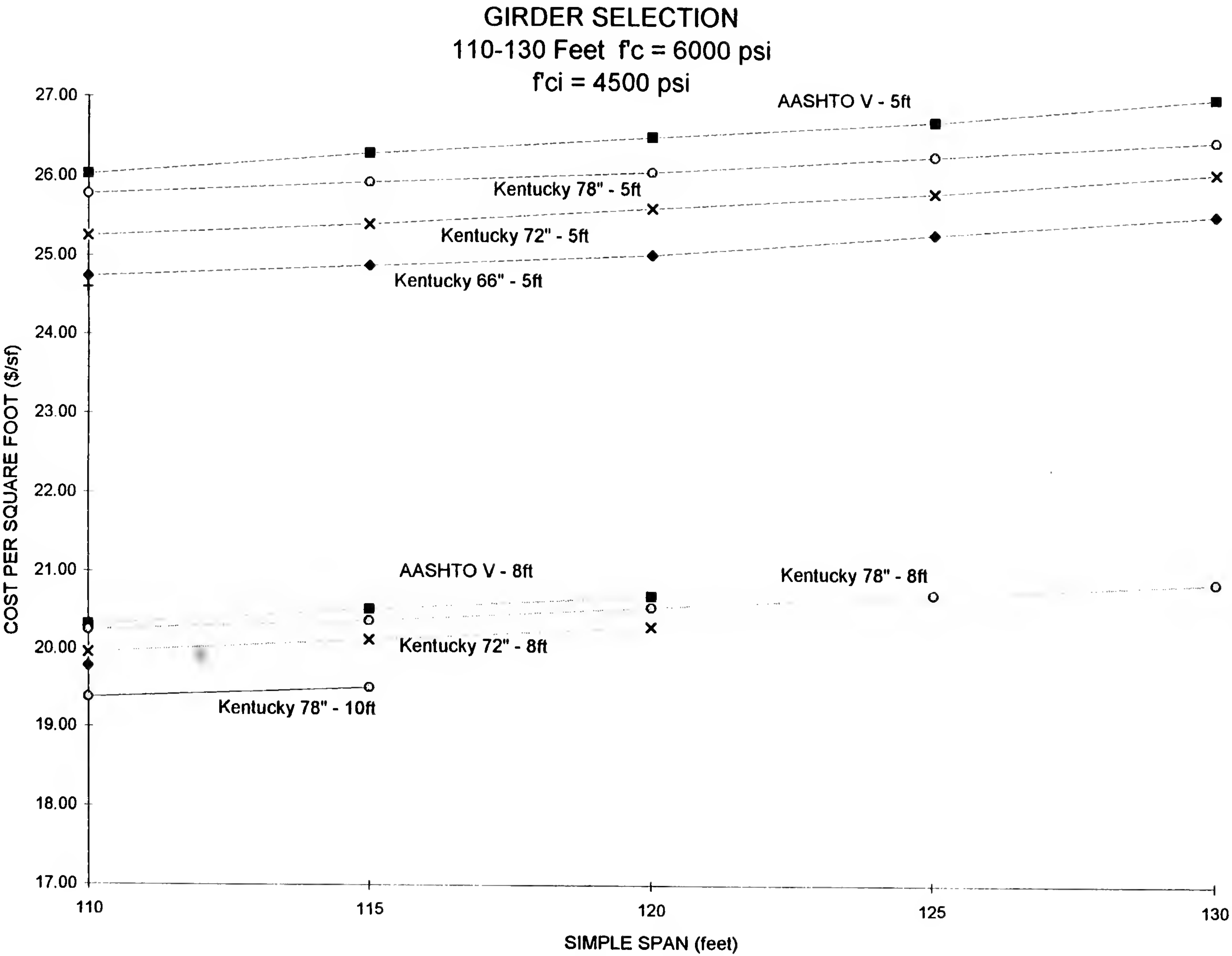


Beam spans may increase 5 to 10 feet when using 7000 psi concrete or continuous spans.

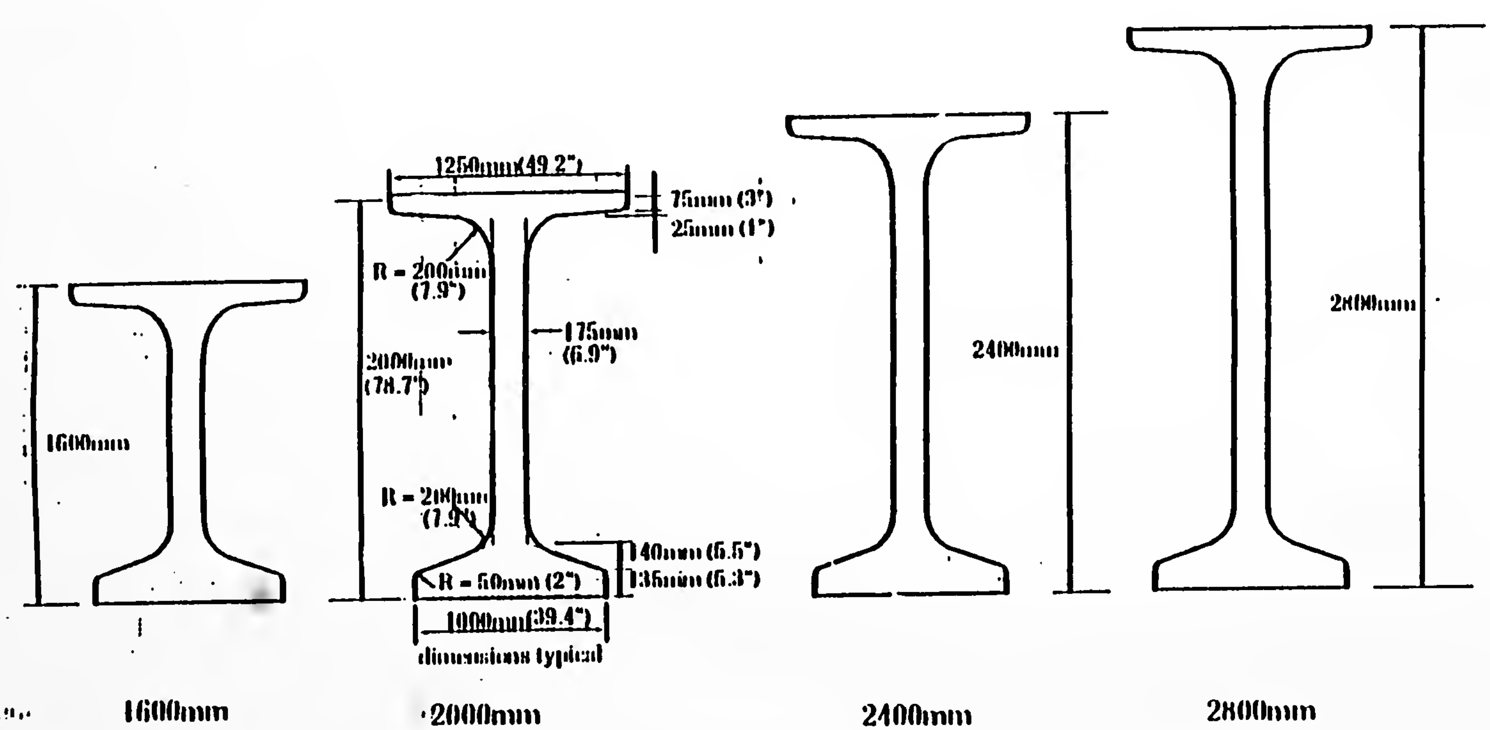

GIRDER SELECTION
30-65 Feet f'c = 6000 psi
f'ci = 4500 psi
COST PER SQUARE FOOT ($/sf)
17.00
16.50
16.00
15.50
15.00
14.50
14.00
13.50
13.00
SIMPLE SPAN (feet)
25
30
35
40
45
50
55
60
65
AASHTO II - 5ft
AASHTO III - 8ft
AASHTO III - 10ft
AASHTO I - 5ft
AASHTO II - 10ft
AASHTO II - 8ft
AASHTO I - 10ft
AASHTO I - 8ft


GIRDER SELECTION
65-90 Feet f'c = 6000 psi
f'ci = 4500 psi
COST PER SQUARE FOOT ($/sf)
20.50
20.00
19.50
19.00
18.50
18.00
17.50
17.00
16.50
16.00
15.50
65
70
75
80
85
90
SIMPLE SPAN (feet)
AASHTO III - 5ft
Kentucky 60" - 8ft
AASHTO IV - 8ft
Kentucky 60" - 10ft
AASHTO IV - 10ft
Illinois 54 - 8ft
AASHTO III - 8ft
Illinois 54 - 10ft


GIRDER SELECTION
90-110 Feet f'c = 6000 psi
f'ci = 4500 psi
COST PER SQUARE FOOT ($/sf)
25.00
24.00
23.00
22.00
21.00
20.00
19.00
18.00
17.00
90
95
100
105
110
SIMPLE SPAN (feet)
Kentucky 60" - 5ft
AASHTO IV - 5ft
Illinois 54 - 5ft
AASHTO V - 8ft
Kentucky 72" - 8ft
Kentucky 66" - 8ft
Kentucky 78" - 10ft
AASHTO V - 10ft
Kentucky 72" - 10ft
Kentucky 66" - 10ft


GIRDER SELECTION
110-130 Feet f'c = 6000 psi
f'ci = 4500 psi
AASHTO V - 5ft
Kentucky 78" - 5ft
Kentucky 72" - 5ft
Kentucky 66" - 5ft
AASHTO V - 8ft
Kentucky 78" - 8ft
Kentucky 72" - 8ft
Kentucky 78" - 10ft
COST PER SQUARE FOOT ($/sf)
27.00
26.00
25.00
24.00
23.00
22.00
21.00
20.00
19.00
18.00
17.00
110
115
120
125
130
SIMPLE SPAN (feet)

Appendix K



Nebraska University Proposed Girder Series.

COVER DESIGN BY ALDO GIORGINI